Taxonomy of Educational Objectives

Pritam Singh

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PREFACE

There is hardly any exaggeration if we say that Benjamin S. Bloom is the father of the science of classification of educational objectives. The first every written handbook of taxonomy of educational objectives in the cognitive domain is indeed a treatise on the framework for educational objectives. For the first time in the history of educational thought this taxonomic classification was developed on the sound footing of logico-psychological basis. In fact this taxonomy is a landmark in providing a theoretical framework for categorisation of educational objectives that provided the direction for objective based teaching and testing.

This taxonomy generated so much interest in the educational field all over the world that researchers started developing other taxonomies as well as on validation of the Bloom's taxonomy. At present quite a few other taxonomies are available not only in the field of cognitive domain but also in the affective and psychomotor domains. In spite of a lot of criticism of this taxonomy, researchers, teachers and evaluators all over the world started using this taxonomy since its inception in 1956. It did not only provide a theoretical basis for teaching and testing but has also facilitated and improved communication among the teachers, evaluators and the pedagogues. Besides, this taxonomy has provided the needed indicators in the form of intended outcomes of learning against which the teaching-learning process can be validated.

As expected umpteen number of studies have been undertaken by researchers to find out the empirical validity of this taxonomy. Most of the researches in this field were based on the tests developed on the six-tier categories of objectives, using varied content base. Likewise, analysis of results undertaken were based on product responses of students without considering the process responses used by students to arrive at those product responses. Similarly, one of the assumptions made by researchers was that the various abilities implied by different categories of objectives are already developed in the instructional programme which indeed was questionable.

The present study undertaken by the author might be unique in this regard that it took into account the need for development of taxonomic test using the same content that form the basis for construction of test items testing all the six levels. Planned and deliberate objective based instruction preceded the testing for different objectives. Besides, validation by product responses was extended to process responses to judge the compatibility of product and process responses. Thus attempt was made in this study to depart from the conventional studies to attempt for more cogent and relevant evidences which may support or reject different hypotheses formulated in connection with empirical validation of this taxonomy.

This study has revealed interesting results related to the five hypotheses framed to test the three basic postulates of 'learned behaviour', 'hierarchy' and 'cumulativeness'. The hierarchy claimed in Bloom's taxonomy is not substantiated by this study. As against the six-tier, only four-tier taxonomy is emerged in order of Knowledge, Comprehension, Application and Evaluation. This provides substantiative support to the three-tier taxonomy in use by the NCERT covering Knowledge, Comprehension and Application Objectives. Cumulativeness of the taxonomy is supported only upto the level of Application while category of Analysis shows inconsistent behaviour while Synthesis appeared to function be at the level of almost Comprehension thereby indicating that cumulativeness of hierarchy of objectives is not clearly demonstrated beyond Application.

Objective based instruction did lead to better performance on higher objectives which indicated the need for adopting process-oriented approach for validation. Hypothesis relating to positive relationship between process responses as identified by students and their product responses as indicated in the answers is not substantiated. Of course, the conclusion is based on very inadequate data and needs more comprehensive data. Perhaps good deal of training of examinees in identifying the mental responses would help them to identify correctly the mental responses. Though data are meagre, there appears to be positive relationship between student-generated and expert-generated hierarchy. Students like experts have more easily identified the mental responses related to Knowledge, Application and Evaluation objectives but are not clear about the Comprehension, Analysis and Synthesis.

In spite of various limitations of this taxonomy, as revealed in this study and studies prior to this, it has provided a good basis for developing theoretical framework of curriculum development, setting and maintaining standards, revitalising instructional practices, reorganisation of learning experiences, designing question papers by examining agencies, emphasising the relevance criterion referenced testing and facilitating administrative decisions. Thus this study has highlighted the need for emphasising objective based instruction and objective based evaluation and indicated the basis for validating the teaching-learning process.

I take this opportunity to express my gratitude to Prof. R. N. Mehrotra, who guided and helped a lot in carrying this project through. I am grateful to Dr. A. E. Harper, who thoroughly scrutinised the thesis and as an external examiner indicated some very useful comments and suggestions which were incorporated in the write-up.

I am indebted to Dr. P. N. Dave and Dr. R. G. Misra for the technical help provided by them in statistical analysis of the data.

I am sure that those teachers, evaluators and researchers who are interested in such validation studies would find this study quite useful. Likewise teachers who are interested in improving students' learning to find useful guidelines in the form of objective based teaching plans and teaching-learning strategies reflected in the study. Above all the evaluators would indeed find a lot of material in the form of basic frame of reference for testing as well as practical guidelines for developing the taxonomic tests which can help them to pass better judgements and more appropriate decisions regarding curriculum, instruction and evaluation.

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1

1.0 INTRODUCTION

There is an increasing tendency in contemporary American theory of education to formulate and apply taxonomy models which depict classification schemes as conceptual frameworks for analysing theoretical as well as practical issues relating to different areas like curriculum, learning, evaluation and administration. All such schemata enable the field workers to think more systematically about how to solve the problems they face. For that theoretical models provide the needed direction.

A model is a product of a particular frame of reference developed through logical and analytical procedures. Its main purpose in education is to describe the relationships among the various components involved in a complex phenomenon. To be useful for a practitioner a model must be logically consistent and empirically verifiable. Logical consistency is a necessary but not a sufficient condition for its use as it may not lend itself to empirical verification. Even logical fitness and intellectual virtuosity may not improve our understanding of or ability to control phenomena. This implies that existence of observable referents for the concepts used in the scheme and verifiability of the relationships indicated in it are the prerequisites to the applicability of a model.

A number of teaching-learning models have been developed. Most of them have some psychological basis. Some of them are the outcomes of association theories, while others have emerged from cognitive theories. Each has its theoretical assumptions and practical implications for instruction and evaluation.

Pavlovian S-R conditioning paradigm, Skinner's operant conditioning and discriminative operant conditioning model emphasise the role of stimulus in evoking an intended behaviour or learning response and its reinforcement. Its practical implications in programmed instruction are well known.

Models of learning based on cognitive theory are many but relevance of David Ausubel (1960), Jerome Bruner (1962) and Robert Gagne (1967) cannot be ignored in the present context. Ausubel's theory of cognitive subsumption is useful in planning lesson sequence by the use of advance organisers which can serve as anchor points. Gagne's model of sequential learning beginning with concrete examplars and elementary skills to the more general and problem solving skills conceptualises the hierarchical process. Thus as contrasted to Ausubel's inclusive concepts to specifics, Gagne prefers specifics-to-generalities hierarchy. Bruner identifies three stages of cognitive human development, enactive, iconic and symbolic corresponding to manipulating the environments, spatial imagery and symbolic inventions. Learning the structure of a discipline is to learn how things are related, he asserts. Its practical implications in emphasising the intellectual skills and the set of principles which forms the structure of a discipline, are quite obvious.

Caroll's (1963) mastery learning model equates degree of learning with the function of time allowed, perservance, aptitude, quality of instruction and student's ability to understand. It has taken a practical shape in the form of criterion-referenced teaching and testing. Glaser's (1962) teaching model depicts the role of objectives and the feedback mechanism essential for pupils' learning and instructional improvement. Flander's (1966) social interaction model stresses the relationship between teacher-pupil interaction and the learning outcomes.

To what extent these models and many others which are not mentioned here, meet the requirement of the learner and the discipline is conditioned by various limiting factors which influence learning. Nevertheless, during the late 1960s several writers have proposed various ways of conceptualising the learning outcomes in more tangible and observable terms on the basis of which systematic educational evaluation should take place. A number of evaluation models are now available from which choice can be made.

Among the goal attainment models pioneer work is that of Ralph W. Tyler (1950) and of Metfessel and Michael (1967). Robert Stake's (1967) Countenance Model distinguishes between descriptive and judgmental act of the evaluator according the antecedents, transactions and outcomes of an educational programme. Among the judgmental models emphasising extrinsic criteria Michael Scriven (1974) makes distinction between formative and summative evaluation, refers to quality of goals, pay off evaluation, comparative evaluation, goal-free evaluation and modus operandi method. Among the decision facilitation models the more commonly known are CSE model of Atkin (1969), the CIPP model of Stifflebeam (1971) and the Discrepancy model of Provus (1971).

All the above mentioned evaluation models are based on different notions of the expected end-product of learning as also the purpose for which appraisal is made. None of these models is ditched in any theoretical frame of reference representing a particular cognitive model of learning. By and large they are attuned to the collection of evidence about the effectiveness of an educational programme.

In an educational setting which represents the will of the society it is more important to prepare students for the goals which are socially desirable. Such socially desirable behaviours need to be identified and scrutinised to tailor them according to the logic of the various disciplines and the psychology of learning. Thus any frame of reference which depicts the intended behaviours that are educationally significant, psychologically sound and socially acceptable is the need of educational planners, teachers and evaluators. Bloom's taxonomy (1956) does provide such a theoretical framework which could be used to improve teaching-learning process.

Since this taxonomy generated a lot of enthusiasm among the curriculum workers a number of validation studies outside India were carried out. The modified version of the taxonomy has been in vogue for the last about three decades in India. The researcher himself has been engaged for more than three decades in the field of educational evaluation at the National Council of Educational Research and Training.

He has been using for a long time the modified version of this taxonomy on an adhoc basis without any empirical evidence on that version. Of late, a number of studies have been undertaken in foreign countries to validate Bloom's taxonomy but none as far as, the researcher's knowledge goes, in the Indian setting. It was in this context that the research got interested in undertaking this project to put to test Bloom's taxonomy in the Indian educational context. This was further necessitated by the ever increasing inquiries from the teachers and the examining agencies as to why the National Council of Educational Research and Training (NCERT) was using a modified version and not the original one as given by Bloom in spite of the fact that for all other purposes the Central Examination Unit of the NCERT which was manned mostly by his disciples, had been using his model. Since this involved a number of issues pertaining to curriculum development, instruction and evaluation which would be ultimately determined by such a framework, it was considered essential to take up the present investigation regarding empirical validity of this taxonomy.

In researching this unexplored area most of the work (Anderson, J.S. 1964 ; Smith, A.B., 1965 ; Kropp, R.P. and Stoker, H.W., 1966; Helgeson, S.L., 1968 ; Smith, R.B., 1968 ; Pichauri, A.C., 1972 ; Anand, C.L., 1973 ; Dave, P.N., 1976) has been done in USA. Pichauri in India used only Helgeson data from USA while Dave and Anand limited their validation studies mainly to the first three objectives of Bloom's taxonomy as adopted by the NCERT. Moreover, the evidence available in foreign studies is not conclusive either way.

Almost all the above-mentioned studies adopted the same approach, that is, product, oriented validation using only product responses as empirical evidence of the taxonomy, the investigator attempted to extend its scope to getting evidence through process based end-product. Another significant dimension added to work in this area is the identification of mental processes also as revealed through students' process responses. Therefore, the present study has not followed the conventional procedure for validation, but has employed non-conventional methodology to determine the empirical consequences or referents of relationships indicated by this taxonomic model of hierarchical learning.

In order to validate Bloom's taxonomy of Education Objectives : Cognitive Domain (1956) the traditional approach is followed as far as the mode of collecting evidences and interpretation is concerned. But with regard to nature of evidences sought, there are clear cut departures which are more innovative for empirical validation of this taxonomy. This applies to the product responses as well as the process responses forming the major part of the data.

With respect to the former aspect attempt was made to make the instrument of evaluation, which was used as a post-test, more valid so as to provide more relevant evidence on pupils' product of learning. Apart from usual steps to make the tool more valid and reliable, deliberate attempt was made to equalise the content over the six taxonomic objectives to ensure collection of evidence that reflected the development of abilities as stipulated in the various objectives and which excluded any effect of the complexity of the content itself should in fact remain only a vehicle of testing. This was sought to be done by constructing an objective-based set of six items on each concept.

Another measure adopted was a deliberate effort to develop that product in the *measurement in which* we were interested. This was ensured by well-planned objective-based teaching by the researcher. This was, however, confined to the experimental group which formed the Sample-B limited to one section only of pupils in contrast to the bigger Sample-A comprising 812 students from eight schools.

Special effort was also made to gather evidence on process responses that were supposed to have helped students to give the product responses. For this a technique was devised to identify mental processes the students used, in order to arrive at the product responses. This part of the study was limited to Sample-C which in turn was a part of Sample-B. For statistical analysis data were computerised and some new analyses were made which are discussed under the relevant chapter.

The present study has no doubt yielded some interesting findings on the nature of cumulative hierarchy of Bloom's taxonomy but at the same time it has generated a number of new issues which need further research to find solutions. This is not new to any venture in the area of research. If one finds solution to one problem he unravels two more the answer to which are unknown. It is expected that the empirical evidence on the taxonomy in this study as also the new methodology adopted will in all probability engender new enthusiasm among the curriculum workers who are interested in the renewal of curricula, measurement of learning outcomes and instructional technology.

2

2.0 ANALYTICAL VIEW OF THE TAXONOMY

Is taxonomy a classification ? Is every classification scheme a taxonomy ? Does classification of educational goals necessarily reflect a taxonomy ? These questions can be answered only if we first try to make an attempt to define 'taxonomy'. The word taxonomy is a borrowed concept from the field of biological sciences where taxonomy is a branch of biology dealing with the classification scheme for plants and animals into various classes, orders, families, genera and species.

Taxonomy or Systematic Botany as the term is used in most of the earlier works has its origin in the Linnaeus method of naming organisms, popularly called the binomial system of nomenclature. According to this nomenclature the scientific name of an organism is constructed by writing, first the name of the genus to which the organism belongs followed by the name of the species of which this particular plant is a member. Just as the related species constitute a genus, so related genera make up a family and families, in turn, an order. Related orders constitute a class and related classes make up a phylum. Thus grades or categories of classification represent a hierarchy like the one of political units i.e., towns, districts, states, nations, continents, hemispheres, etc.

2.01 TAXONOMY VERSUS CLASSIFICATION

Classification system may be based on arbitrary criteria like size, shape, uses, number of stamens, etc., or based on natural relationships or true affinities of similar plants. The former is the artificial system while the latter is the natural system of classification. Plants can be classified on the basis of size e.g., herbs, shrubs and trees. They can be categorised as mesophytes, xerophytes, hydrophytes, etc., on the basis of their habitats. Likewise, plants can be classified as medicinal and non-medicinal ; ornamental or horticultural and in many other ways irrespective of any natural relationship existing among them. Thus, the basis in artificial system of classification is arbitrary and for its validation any criterion may be used. On the other hand in a natural system of classification any and every basis would not work. There has to be some order and relationship which runs through the whole system of classification. It reflects evolution of organisms vis-a-vis their groups into which they are classified. Natural order reflecting evolutionary relationships among the members of organisms is, therefore, the basis of classification in the taxonomy of organisms. Taxonomy can be validated by demonstrating its consistency with the theoretical views it attempts to order.

Thus a taxonomy is a type of classification and any particular classification system based on natural relationships becomes a taxonomy. Every taxonomy is, therefore, a classificatory scheme but every classification system need not necessarily be a taxonomy. Bloom's classification of educational goals from this point of view can be considered a taxonomic classification but not in the true sense of the natural system of Systematic Botany. It is taxonomic in the sense that Knowledge (K) like a Species (S) becomes a part of Comprehension (C) comparable to Genus (G). Likewise Application (AP) is comparable to 'Family' (F), Analysis (AN) to Order (O), Synthesis (S) to 'Class' (Cl) and Evaluation (E) to 'Phylum' (P). Similarity in the hierarchy in both the systems can be depicted as :

Biological System : $S \rightarrow G \rightarrow F \rightarrow O \rightarrow Cl \rightarrow P$
Bloom's System : $K \rightarrow C \rightarrow AP \rightarrow AN \rightarrow S \rightarrow E$

But when we go further into subdivisions in each system it would reveal that the relationship is analogous and not homologous in nature. When hierarchy is considered in terms of only one organism which can be represented by its species, genus, family, order, class and phylum, the taxonomy of objectives ranging from K to E is quite different as can be observed from the following symbolic representation :

Table 1

BIOLOGICAL SYSTEM AND BLOOM'S SYSTEM OF CLASSIFICATION COMPARED

BIOLOGICAL TAXONOMY	BLOOM'S TAXONOMY
1. $Ch_1+Ch_2+Ch_3+\cdots=Sp$	1. $Ch_1+Ch_2+Ch_3+\cdots=K$
2. $Sp_1+Sp_2+Sp_3+\cdots=G$	2. $K+p\cdots\cdots\cdots\cdots=C$
3. $G_1+G_2+G_3+\cdots=F$	3. $C+q\cdots\cdots\cdots\cdots=AP$
4. $F_1+F_2+F_3+\cdots=O$	4. $AP+r\cdots\cdots\cdots\cdots=AN$
5. $O_1+O_2+O_3+\cdots=Cl$	5. $AN+s\cdots\cdots\cdots\cdots=S$
6. $Cl_1+Cl_2+Cl_3=\cdots=P$	6. $S+t\cdots\cdots\cdots\cdots=E$

1. Ch—Characteristic
2. p, q, r, s, t indicate additional character/component at different levels.

From this comparative view it is obvious that in plant taxonomy it is exclusiveness of the characteristic which is significant for categorisation while in Bloom's taxonomy it is the inclusiveness of the behaviours of the preceding objective which is more important. In other words, independence and complexity of characters in the former and cumulativeness and complexity of behaviours in the latter are observable. Functionally, in the former, the complexity lies at the lowest level i.e., 'Species' where one species is more complex than others e.g., $\ldots Sp_3 > Sp_2 > Sp_1$. Once this is identified further classification into genera, families, etc., is only theoretical rather than functional. This is not true of Bloom's taxonomy because here the maximum complexity is at the highest level 'Evaluation' and not at the lowest level, 'Knowledge'. Indeed it goes on increasing from K to E.

One of the theoretical implications of such a difference will be that if biological concept of taxonomy is strictly followed, Bloom's taxonomy should have listed all the behaviours like recall, translation, interpretation, etc., in order of their complexity and then classified them into six categories independent of each other without overlapping of one category of objective by the next one in the hierarchy.

2.02 THE SIX-TIER TAXONOMY

Bloom's taxonomy identifies six levels of objectives which are arranged in rank order of Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation the least complex being the 'Knowledge' category. Each of these categories of objectives is defined in terms of observable behaviours. Essential attributes of each level of the taxonomy are given as under based on instrumentation by Metfessel and his associates (1969).

Objectives		*Essential Attributes Expected*
1. Knowledge	: K	To recall, recognise, identify, acquire and define, vocabulary, terminology, definitions, facts, examples, properties events, phenomena, etc.
2. Comprehension	: C	To translate, transform, illustrate, read, rephrase, restate, interpret, reorder, rearrange, distinguish, demonstrate, extend, interpolate, use, classify, infer, estimate and extrapolate, samples, definitions, abstractions, relationships, conclusions, implications methods, etc.
3. Application	: AP	To generalise, develop, organise, restructure, predict and establish, principles, processes, abstractions, phenomena, theories, effects, etc.
4. Analysis	: AN	To compare, contrast, identify, relate, distinguish, deduce recognise, discriminate, detect and classify elements, conclusions, hypotheses, arguments, relevancies, fallacies, consistencies, assumptions. patterns, techniques, views, structures, etc.
5. Synthesis	: S	To produce, constitute, originate, document, modify, propose, plan, design, specify, derive, develop, reorganise, and formulate structures, patterns, designs, communication, composition scheme, taxonomies, hypotheses, generalisations, abstractions, etc.
6. Evaluation	: E	To argue, judge, assess, validate, appraise, standardise, decide and scruitinise, accuracies, consistencies, fallacies, flaws, standards, theories, alternatives, generalisations, designs, procedures, reliability, validity, etc.

2.03 SUB-CLASSES OF THE TAXONOMY

According to Bloom's taxonomy (1956) each of the six classes of objectives mentioned above is further divided into sub-classes which determine the nature and scope of each class of objective ranging from Knowledge to Evaluation :

K (*Knowledge*)

K-1. Knowledge of specifics	(i) Knowledge of terminology (ii) Knowledge of specific facts
K-2. Knowledge of ways and means dealing with specifics	(i) Knowlegde of conventions (ii) Knowledge of trends and sequences (iii) Knowledge of classifications and categories

(iv) Knowledge of criteria
(v) Knowledge of methodology

K-3. Knowledge of universals and abstractions in a field
(i) Knowledge of principles and generalisations
(ii) Knowledge of theories and structures

C (*Comprehension*)
    C-1. Translation
    C-2. Interpretation
    C-3. Extrapolation
AP (*Application*)
AN (*Analysis*)
    AN-1. Analysis of elements
    AN-2. Analysis of relationships
    AN-3. Analysis of organisational principles
S (*Synthesis*)
    S-1. Production of unique communication
    S-2. Production of a plan or proposed set of operations
    S-3. Derivation of a set of abstract relations
E (*Evaluation*)
    E-1. Judgments in terms of internal evidence
    E-2. Judgments in terms of external criteria

2.04 CONCEPT OF OBJECTIVE IN THE TAXONOMY

According to the taxonomy an objective is a normative concept, being a product of value judgment. It carries with it social acceptance. Therefore, all those behaviours which students should exhibit as a result of having educative experiences and which are socially desirable are represented in the statements of educational objectives. What is classified is the students' behaviours which represent the intended outcomes of the educational process. It has been assumed that the same classes of behaviours may be observed in the usual range of subject matter content at different levels of education. It is not the instructional methods or materials or the content which are classified but the intended behaviour of the students. Such intended behaviours which relate to the mental acts or thinking are included in this taxonomy of educational objectives : cognitive domain. Since intended behaviours represent the social goals imposed by culture or society on the youngsters, the undesirable and abnormal behaviours do not find place in this compendium. Major purpose of taxonomy being better communication among teachers and curriculum workers, preference is given to those human behaviours which the educators and not the psychologists, visualise. Nevertheless, all intended behaviours included in this taxonomy are consistent with the relevant and accepted principles and theories of learning.

Attempts have been made to define each objective in terms of observable behaviours which can be described and classified in terms of logic of complexity. To offset the danger of atomisation and fragmentation of the objective, effort has been made to set the taxonomy at a proper level of generality. Statement of illustrative objectives as given in the taxonomy reflects two dimensions of an objective, the ability or the behaviour (intended) part and the content or subject matter part. The former depicts the modification part of students' behaviour while the latter indicates the medium or the operational area through which the change in the behaviour is to be brought about. This taxonomy is based on the first part dealing with the students' intended behaviours which it seeks to explain, correlate, specify, illustrate, order and classify to provide the needed basis for better communication among the planners, teachers, administrators, curriculum developers and evaluators.

2.05 EDUCATIONAL-LOGICAL-PSYCHOLOGICAL BASIS

As described earlier the taxonomy as a classification device incorporates the intended or the desired behaviours. Methodology of its development is clearly indicative of the deliberate attempt made to scruitinise the teacher-made materials, plans, tests and other sources to prepare the long list of educational objectives. These educational antecedants, transactions and learning outcomes with which the practitioners in educational institutions are involved were the criteria of selecting, formulating and stating the educational objectives. Thus taxonomy development had its take off from the educational ground where it ultimately had to land for its implementation.

The taxonomy is logical in that each term is defined precisely and used consistently throughout the text. Classification system adopted in this treatise is analogous to the Dewey Decimal System of classifying books. It provides precise and usable definitions of symbols which are designated for various classes of objectives. There is further consistency in presenting the illustrative material in the second part of the taxonomy. Every major objective is discussed to highlight its nature and scope followed by an explanation of the types of behaviours, i.e., subclasses. Each subclass is illustrated by the abilities implied under it, called the illustrative educational objectives. This, in turn, is followed by the illustrative test items under each subcategory. Therefore, the logical consistency forms another basis of taxonomy.

That the taxonomy has a psychological basis too, is evident from its relevance to the accepted principles of psychology and theories of learning. Arrangement of educationally intended behaviours from simple to most complex in major six categories and subcategories, the sequential learning in terms of learning proposed ; emphasis on five out of six classes dealing with intellectual skills, which provides for more transfer value ; preference of social behaviours and neglect of abnormal and undesirable behaviours as intended behaviours, are characteristics which reflect the psychological basis of the taxonomy. It is purely on a prior descriptive scheme in which every type of educational goal can be represented in a neutral fashion without having any implication of value judgments and content of discipline.

2.06 THE FOUR POSTULATES

All the above-mentioned features of Bloom's taxonomy rest on the following postulates :

(i) Stipulated processes in the taxonomy are cognitive.
(ii) Mental processes designated in the taxonomy are learned behaviours.
(iii) Arrangement of categories is hierarchical.
(iv) Hierarchy of categories is cumulative.

The first postulate is related to the nature of intended behaviours which this taxonomy attempts to classify. Only those behaviours of students which reflect the learning outcomes of their participation in some unit of instruction could be classified. This includes the way, the students think, feel or act corresponding to cognitive, affective and psychomotor areas. In this taxonomy only those intended behaviours are included which relate to mental or cognitive acts. Therefore, behaviours like appreciations, interests, attitudes, values, and psychomotor skills do not find place in this taxonomy of cognitive domain. In the present investigation no attempt was made to explore the validity of those behaviours or their comprehensiveness to sample the cognitive development. The cognitive processes designated in the taxonomy are taken for granted.

Regarding the second postulate that 'mental processes are learned behaviours' it is assumed in the taxonomy that learning is reinforced with practice. As such recurrent use of concepts over a period of time improves one's understanding and manipulativeness. Continual use and feed-back not only reinforce learning but also improve transfer of learning and transfer of principles. Therefore, the improvement in students' achievement over the grades is the issue that was investigated in the present study.

Besides, the other two postulates are crucial from the point of view of validation. According to the third postulate the six objectives K to E are arranged in order of hierarchy ranging from the most simple 'Knowledge' to the most complex 'Evaluation'. This means that the cognitive process implied under the Knowledge objective are simpler than those under Comprehension. Likewise the complexity of these processes goes on increasing. It may be represented as $K \angle C \angle AP \angle AN \angle S \angle E$. Such a system of classification in which various objectives are arranged in increasing complexity of the mental processes is called hierarchical.

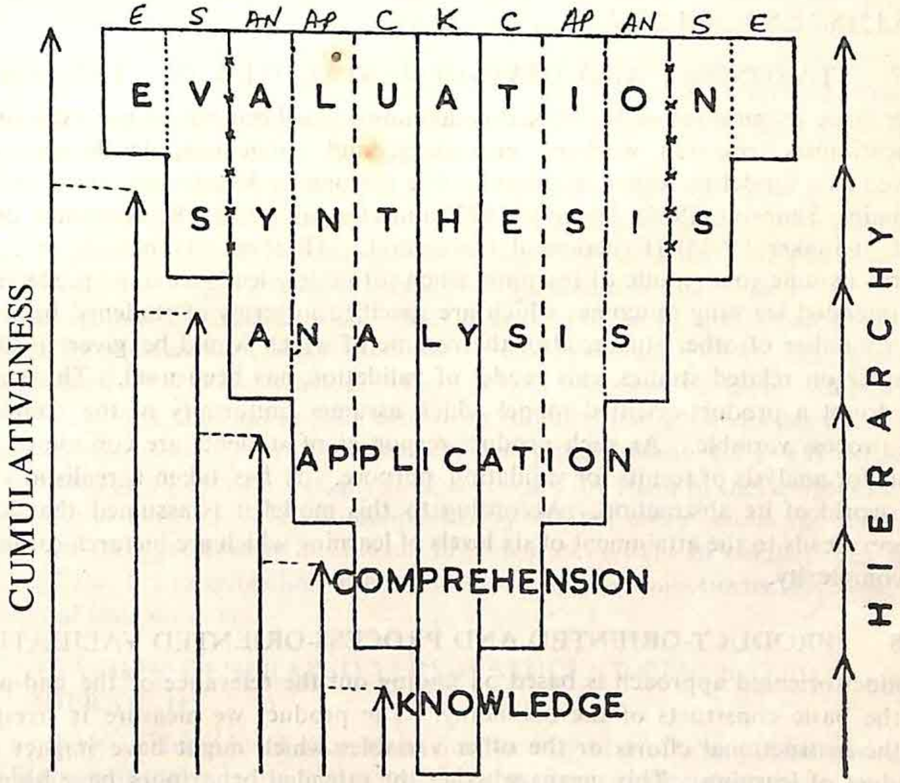
Besides hierarchical nature of the taxonomy, each category of objective is claimed to be included in the next higher category of objectives. Thus each objective except that of Knowledge which represents the lower most category, carries with it the cognitive processes of all the objectives that precede, plus an additional component of its own. This can be represented as $K \subset C \subset AP \subset AN \subset S \subset E$. Thus K is a subset of C which becomes a subset of AP and so on.

Thus as we move from lower level objective to the higher level objective, the cognitive processes go on accumulating from category to category till we reach the highest category 'Evaluation' which is supposed to include all the previous five categories plus a unique component of its own. It means that each successive category in the hierarchy is built upon the cognitive processes of the category that precedes. This also means that cognitive processes at successive levels go on merging as we move from K to E. If K includes a mental process 'a' then C includes 'ab', AP includes 'abc', AN includes 'abcd', S includes 'abcde' and E includes 'abcdef'. Such an organisation of hierarchy is cumulative in nature.

For better understanding, cumulativeness and hierarchical nature of taxonomy of these six objectives representing the cognitive domain it can be graphically depicted in the form of diagram as shown in Fig. I (on next page).

Cumulative Hierarchy in
Taxonomy of Educational Objectives

Fig-1



For visualizing the hierarchy of objectives (K to E) in relation to increasing complexity of each as also the tube-within-tube type of cumulativeness of this taxonomy a scheme like the following may be useful to illustrate the principle underlying :

$K=a$
$C=a+\ ?$
$AP=a+b+\ ?$
$AN=a+b+c+\ ?$
$S=a+b+c+d+\ ?$
$E=a+b+c+d+e+\ ?$

OR

$K=a$
$C=a+b$
$AP=a+b+c$
$AN=a+b+c+d$
$S=a+b+c+d+e$
$E=a+b+c+d+e+f$

Alternatively

$K=K$ $\quad$ K
$C=K+\ ?$ $\quad$ $K \subset C$
$AP=K+C+\ ?$ *OR* $K \subset C \subset AP$
$AN=K+C+AP+\ ?$ $\quad$ $K \subset C \subset AP \subset AN$
$S=K+C+AP+AN+\ ?$ $\quad$ $K \subset C \subset AP \subset AN \subset S$
$E=K+C+AP+AN+S+\ ?$ $\quad$ $K \subset C \subset APA \subset N \subset S \subset E$

OR

$$E \supset S \supset AN \supset AP \supset C \supset K$$

Within each category of broad objective, hierarchy can be expressed as under in accordance with the list of sub-categories given under each objective on page 7 and 8 of this chapter : $K.1 \subset K.2 \subset K.3 \subset C.1 \subset C.2 \subset C.3 \subset AP \subset AN.1 \subset AN.2 \subset AN.3 \subset S.1 \supset S.2 \subset S.3 \subset E.1 \subset E.2$

2.07 TAXONOMY AND DEVELOPMENTAL VIEW OF LEARNING

Ever since its publication in 1956, this taxonomy has been put to use extensively by educationists, research workers, evaluators, and curriculum developers. It has served as a model for other taxonomies like the one by Krathwhol (1964) (Affective domain), Simpson (1966), Harrow (1972) and Hannah (1975) (Psychomotor domain) and Steinaker (1975) (Experiential taxonomy). All these taxonomies and related works assume some mode of learning, whch ultimately leads to some predetermined or intended learning outcomes which are specified in terms of students' behaviours. In a number of other studies also, the resume of which would be given in the next chapter on related studies, this model of validation has been used. This model is no doubt a product-oriented model which assumes uniformity of the content and the process variable. As such product responses of students are considered as the basis for analysis of results for validation purpose. It has taken a realistic view of the world of its abstraction. According to this model it is assumed that learning process leads to the attainment of six levels of learning which are hierarchical in terms of complexity.

2.08 PRODUCT-ORIENTED AND PROCESS-ORIENTED VALIDATION

Product-oriented approach is based on finding out the relevance of the end-product to the basic constructs of the taxonomy. The product we measure is irrespective of the instructional efforts or the other variables which might have impact on the product of learning. This means whether the intended behaviours have been developed or not, students are to be tested for their achievement or learning on all the six objectives. In contrast to this, process based validation emphasises the need for developing those behaviours which are intended as the end-product of learning, through deliberate and planned instructional efforts before the students are tested. Thus the product-oriented approach is independent of the process of development while process-oriented approach is based on the concept of integral relationship between objective-based testing and objective-based instruction. In the present study both these approaches have been tried.

In his paper titled 'Developing a Cognitive Model of Learning' Dave (1972) has highlighted the importance of content input and the process interaction variables which must be controlled or manipulated while undertaking any research on learning outcomes. The usual research procedure in this area has been to study the product and analyse it to demonstrate the validity of the model. This has not been found satisfactory as the question arises whether the interaction between the content input and the processes can be wisely neglected in this type of study. A fundamental objection raised by Dave against this procedure is, 'Should the educator evaluate a product which is not purposefully developed and in all probabilities might not have been developed ?' The basic point in this approach is the recognition of developmental nature of abilities implied under each category, as differentiated from primary mental abilities.

In such an approach deliberate teaching for development of such abilities like interpretation, application, analysis, etc., has to be undertaken before evaluating the product. This, in turn, assumes a preplanned objective based instructional and evaluation material especially designed for use in teaching with a focus on the development of concerned abilities. In the present study this was worked out and tried out on a limited sample of class IX students to gather evidence about one of the hypotheses listed in the chapter on statement of problem.

Apart from process oriented approach based on developmental view of learning, attempt has been made in this study to verify the cumulative hierarchy of objectives on the basis of product of performance irrespective of the process of performance. More often than not, the validation studies of this taxonomy have been undertaken using final product as the base data. This is substantiated by a number of studies like those by McKeachie (1962), McGuire (1963), Anderson (1964), Smith, R. B. (1968), Pachauri (1971) and Dave & Anand (1973). In none of these studies the variable of 'content' was kept under control as different content elements were used for framing test items. To obviate this deficiency the present study was extended to use product-based data on a bigger sample and see the effect of the taxonomic test in which the content variable was controlled by making every set of six questions (6 levels), on the same content. This has provided useful data to compare the effectiveness of the two approaches, process-oriented and product-oriented, used for validation of the taxonomy.

2.09 TEACHER-GENERATED VERSUS STUDENT-GENERATED HIERARCHY

When we think of hierarchy in learning as proposed by Gagne (1965) or as envisaged in the Bloom's taxonomic model (1956) of evaluation it is intended that a teacher, given the requisite conditions can lead to the development of such abilities in the hierarchical order. This assumption when applied to the present taxonomy model presupposes the existence of such a hierarchy which, in fact, is only teacher-generated and can be questioned on the basis of evidence that might accrue from students' responses. A taxonomical test when administered to a student and his responses analysed in terms of mental processes (as implied in the various objectives) may not yield a similar hierarchy as claimed in the taxonomical model. Unless the student exercises the same mental processes or is obliged to use the same ability as is sought to be included in the question the hierarchy generated by the student, as revealed through his process responses may not be the same as the teacher-projected hierarchy. This issue is quite ticklish and difficult to verify. However, a modest attempt in this direction was made with one of the sections of class IX which was used as an experimental group for testing the relevant hypothesis.

2.10 MODES OF VALIDATION

From the foregoing description of taxonomy of educational objectives and the issues involved therein, following approaches can be identified for validation purposes :

(a) Validation of learning outcomes irrespective of the content input and the process leading to development of those outcomes (product).
(b) Validation of learning outcomes resulting from the use of equivalent content but without regard to the process involved in that product of learning.
(c) Validation of product of learning which is developed through the use of equivalent content and deliberate use of specified process of teaching and learning.
(d) Validation of learning outcomes (product) in terms of actual use of mental processes that lead to the correct response on the questions testing predetermined abilities implied in an objective.

The first mode has been adopted by most of the investigators who used stray items testing different objectives. The usual technique is selection of items from different test pools and classifying them objective-wise. For reasons discussed earlier in this chapter, this mode was not used in this investigation. Remaining modes are put to use for testing one or the other hypothesis. The rationale for each is discussed in the next chapter.

One of the hurdles in validating the taxonomy is the construction of a measuring instrument which yields content-impact-free achievement scores. This can be achieved by designing the measuring tool in such a way that the evidence that accrues from it reflects the real achievement in terms of abilities implied by each objective. Another hurdle usually faced is the designing of the instructional material and organisation of learning experiences that facilitate development of objectives in the attainment of which we are interested. The most difficult task is however, the identification and analysis of the mental processes that the students use in answering an item. Since verbalisation of the mental processes is a very difficult process, some practicable methodology had to be devised after preliminary tryout.

2.11 THEORETICAL OBJECTIONS ON THE TAXONOMY

General utility of the system of classifying cognitive behaviours developed by Bloom and his associates cannot be over-emphasised. Nevertheless, a number of objections can be raised concerning knowledge objective, the hierarchical order, degree of specificity and limitation of written tests for measuring higher level processes. Each one of these is briefly discussed below on the same line as those of Tanner (1972).

(i) THE KNOWLEDGE CONCEPT

As defined by Bloom and his associates (1956) in the subclasses, 'Knowledge' is represented by nothing more than simple recall of information which involves little more than remembering of facts, phenomena or processes. This limited meaning of 'Knowledge' is objected to by professionals like Dewey (1916) who viewed knowledge as those behaviours that 'render our action intelligent', whereas 'information served from thoughtful action...is a most powerful obstacle to further growth in the grace of intelligence.' Because many educators do not equate knowledge with simple recall of information, this usage of 'Knowledge' in the taxonomy is not acceptable. For them 'recall of information' seems to be more appropriate than that of the term 'Knowledge' used in Bloom's taxonomy.

(ii) HIERARCHY AND COMPLEXITY

Taxonomy is based on the premise that cognitive learning occurs in sequential order ranging from simple to complex behaviours. Whitehead (1929) challenged the criterion of difficulty by which school studies are arranged and classified. 'It is not true that easier subjects should precede the harder......the postponement of difficulty is no safe clue for the maze of educational practice.' It is argued that learning of element of a phenomenon or concept as an antecedent to the understanding and utilisation of material would mean that a child should learn the alphabet first and then learn to speak. In fact, it is easier to learn a seemingly complex abstraction when properly understood in a concrete life situation than to learn individual elements of an abstraction, not applicable to life situation. Thus the components of a phenomenon may be learnt after the phenomenon is generally understood. Thus, arrangement of phenomena is better understood in interaction than merely on logical basis. Hierarchical order of instructional objectives developed by Bloom and his associates may, therefore, be supported on logical grounds but not on psychological or ecological basis. On this logic, comprehension may be integral to any task, simple or complex, rather than it be only a form of behaviour more abstract than knowledge.

(iii) NON-COGNIZANCE OF INTEGRATIVE SKILLS

Although a number of specific behaviours are listed which are basic to problem-solving, yet the taxonomy does not focus on these behaviours per se. Thus a student may not be aware of the overall process of problem-solving although he may be involved in a wide range of cognitive activities. There is a lot of disagreement as to the degree of specificity necessary for formulating objectives. What is expected is that students should be aware of the relationships between various cognitive skills and the processes of problem-solving and inquiry-discovery.

(iv) LIMITATIONS IN EVALUATING CREATIVE PROCESSES

Bloom, Hastings and Madaus (1971) acknowledge that the taxonomy mostly represents convergent thinking but they do point out that divergent thinking and creative thinking are possible when the student engages in synthesis. Since paper-pencil tests impose time and speed restrictions, it is no doubt that they cannot stimulate creative thinking to any considerable extent. Moreover, measuring creative responses quantitatively by such tests is difficult and has inherent limitations as an educational objective.

These are some of the more tangible objections raised by different educators. But this should not deter us from getting empirical evidence about the taxonomy developed by Bloom and his associates.

2.12 NEED FOR EMPIRICAL VALIDATION

According to the authors of the taxonomy, the measurement of the validity of taxonomy requires finding out the extent to which it is a set of classification ordered or arranged on the basis of a single principle or a consistent set of principles or is an agreement with the empirical evidence ; whether the way in which classifications are ordered, corresponds to a real order among the relevant phenomena ; to what extent it is consistent with the sound theoretical views available in the field. It implies that more complex objectives are more difficult to learn and test questions intended to test higher cognitive objectives are more difficult to attempt than those intended to test less complex objectives.

The need for empirical validation of the taxonomy in the Indian context was warranted by a number of factors which are detailed below :

(a) Bloom's taxonomy in modified form is in vogue in India since early sixties but no evidence was available to support or refute the three tier taxonomy vis., Knowledge, Understanding and Application in use by the National Council of Educational Research and Training.

(b) Six tier taxonomy of Bloom and his associates appears to be too cumbersome to apply keeping in view the availability of competent teachers and facilities of computerisation of data. Need for a much simpler and usable list of objectives was warranted.

(c) Analysis of question papers and evaluation of answer scripts for almost all Boards of Secondary Education conducting public examinations in India reveals that teaching is done at a level which does not result in students' achievement beyond comprehension level. We must know whether it is possible to really teach students for developing higher level objectives like Application, Analysis, Synthesis and Evaluation. This would then help in validating testing against teaching.

(d) Since written examinations now prevalent in India are the main devices of appraising students' attainments in cognitive domain, it is necessary to know if they really test divergent and creative abilities of students within the restraint of time. If not, then development and assessment of these abilities can be emphasised in teaching-learning strategies as well as in testing and evaluation.

(e) If empirical evidence in favour of proposed postulates of hierarchy becomes available, the emphasis could be shifted from teaching for content to teaching for development of intended learning outcomes (behaviours) using content as a medium for development of those behaviours.

(f) Curriculum development is at present a haphazard activity. On the basis of empirical evidence about taxonomy, the objectives of various disciplines can be reformulated which can form the basis of development of courses for students, adopting instructional strategies and evaluation procedures.

(g) With a shift from external examinations to teachers' assessment and evaluation in schools by teachers more stress is envisaged on the formative evaluation. This involves specially designed evaluation material for use in unit testing, diagnostic testing and testing for mastery learning and development of question banks. Empirical evidence can provide the list of criterion behaviours which can be categorised into major classes which would then become the basis of framing questions based on predetermined objectives, for use in question banks and teaching-learning strategies.

(h) Under the new pattern of 10-year schooling for general education, a heavy curriculum load is the concern of educational workers today. One of the fundamental means for reducing it is to chisel off the overlapping and repetitive content from each discipline. But what criteria should govern this, can be traced to the intellectual skills or process objectives which indeed are the basic tools for further learing and are more important than learning of subject content. Empirical validation would reveal the independence of certain intellectual abilities which may be made the focus of selection of the content.

In that case, coverage of intellectual abilities would be preferred to the content of a discipline. A lot of content from different subject matter curriculum will give way to social issue-based curriculum in which social adjustment, social implications, problem solving approach and attitude building would receive more attention. This is what is needed in a general education curriculum. Validation study can hopefully provide the list as well as the sequence of development of such intellectual skills and problem-solving abilities in the form of intended outcomes of learning.

From the foregoing discussion it becomes quite evident that validation studies like the one undertaken here can go a long way in meeting the needs of curriculum developers in general and evaluators in particular. Details of the various attempts made in this direction are given in the chapter that follows.

3

3.0 REVIEW OF EMPIRICAL STUDIES—A RETROSPECT

It has been pointed in the previous chapter that Bloom's taxonomy of educational objectives, is basically an evaluation model. Nevertheless, it indirectly reflects the cognitive model of learning hierarchies. It seeks to measure the product of learning which may or may not be the outcome of planned and deliberate effort. In education the technology of measurement is not as important and significant as a sound educational philosophy. It is this philosophy that determines the selection and classification of objectives. If one knows what constitutes achievement of a learner, he is aware of what to measure. 'What knowledge is of most worth ?' This was the question which Herbert Spencer (1861) asked and tried to answer.

What is worth teaching or learning is a question of values which is translated in the form of objectives. For this, there is need for theoretical framework which takes into account the needs of the learner, demand of the society, psychology of learning and requirements of the discipline. Depending upon what constitutes an objective and the frame of reference, listing and classification of objectives can be done in accordance with the criteria selected for the purpose. A number of attempts in this direction have been made even before Bloom's taxonomy to categorise the educational objectives. A brief resume of these may be useful to understand the underlying philosophy and for developing a point of view. These are categorised under two headings ; the pre-Bloomian attempts and post-Bloomian taxonomy studies undertaken in India.

3.1 PRE-BLOOMIAN ATTEMPTS

One of the earliest classification schemes is found in Herbert Spencer's (1861) essays on the purpose of education. He categorised the activities in what constitutes human life, into five ; namely, self-preservation, securing the necessity of life, rearing and discipline of offsprings, maintenance of proper social and political relations and gratification of taste and feelings. The Commission on Reorganisation of Secondary Education (1918) redirected its emphasis by formulating seven cardinal principles as the main objectives of education namely ; Health, Command of Fundamental Processes, Worthy Home Membership, Vocation, Citizenship, Worthy Use of Leisure and Ethical Character.

Since the introduction of General Science in school curriculum in the first decade of this century a number of attempts to list objectives under various categories have been made. One of the earliest attempt was made by Crecelius (1923) who emphasised the need for acquaintance with the laws of nature necessary for health, information about appliances of science useful for convenience and comfort, playful manipulation of toys, machines, etc., and applications of sciences in public utilities. Watkins (1924) investigated the objectives for General Science and categorised them into seven. Cureton (1927) listed five objectives related to appreciation, attitudes, interest, habits, facts and general purview of science.

Craige (1931) listed three criteria for selecting objectives namely, those influencing thought reactions, functional in terms of health, economy, etc., and those essential for interpretation. Robertson (1933), Pruitt (1935), Croxton (1937), Winters (1937), Beachamp, Mayfield and West (1941), Martin (1944), National Society for the Study of Education (1947) and Blough (1948) listed objectives in science into various categories in different ways emphasising different aspects.

Thomas Woody (1931) refers to Benjamin Franklin who recognised the problem in same manner as Spencer (1961). According to him, 'It would be well if they could be taught everything that is useful and ornamental : but art is long and the time is short. It is, therefore, proposed that they learn those things that are likely to be most useful and most ornamental.'

Research has evinced considerable belief that one who knows can also apply his information. Johnson (1934) found that ability to acquire information is accompanied by the ability to apply, to a substantial extent. Burich (1934) found that 13 sub-tests of a comprehension examination designed to measure achievement of 13 objectives of an English course were so inter-related as to 'indicate practically no relationship between achievement in terms of some objectives while between others it is relatively high'. Fotos and Remmers (1934) while working with objectives and examination in French found a high relationship between vocabulary, English to French translation, and French to English translation of knowledge of verb forms, and concluded that 'language pattern tends to develop as a whole'.

Tyler (1936) found low correlations among tests on recall of information, ability to apply and ability to draw inference thereby concluding that there is no correspondence between achievement on recall of information and higher abilities.

McConnel (1940) working on three types of objectives i.e., knowledge of vocabulary, knowledge of facts and knowledge of principles, found that difference in what an item measured was greater in subject-matter sections than between types of objectives, meaning thereby that different objectives differed less among themselves than did the subject-matter division.

Wittenborn and Larson (1944) found intercorrelations from 0.60 to 0.75 between achievement scores in German reading vocabulary and grammar, and correlations of from 0.50 to 0.59 between semester grades and these achievement scores. Flanagan (1950) proposed empirical approach to the formulation of educational goals using critical incidence technique used in industrial psychology. The basis in this case was to collect and classify the effective and ineffective behaviours in a particular activity and thus to list the critical requirements for success in an activity. Such critical incidents formed the list of objectives. Furst (1950) reported low median correlations among 29 measures of achievement of different objectives of general education for high school and college students over a period of two years instruction. Dressel and Mayhew (1954) studied that in order to have significant growth in the more complex objectives emphasis must be given to all those through learning and environment. This study points out that development of particular abilities through teaching is a prerequisite to testing students for those abilities.

All the attempts made before the taxonomy was propounded by Bloom and his associates indicate that types of objectives emphasised ranged from simple information and intellectual skills to that of appreciation, interests and attitude development. Since categorisation of objectives differs quite widely in its scope and emphasis it is quite obvious that criteria used for enunciating and classification differed from author to author. This was so because in none of these studies there was any particular theoretical framework which could provide the necessary guidelines. In the absence of such a frame of reference it is not unlikely that nature, scope, relevance, complexity and comprehensiveness of the objectives formulated, may not be taken care of. This is the reason why in the absence of a well knit set of objectives, curriculum development projects up to the early fifties were not so well directed as we find from late fifties onward.

3.2 POST-BLOOMIAN-TAXONOMY EFFORTS

Formulation of objectives in behavioural terms attracted the attention of the curriculum workers during the fifties. The most outstanding and internationally known effort made in classification of educational objectives is that of Bloom and his associates (1956). It was this taxonomy that lead to the movement of specifying the objectives and development of taxonomies.

3.2.1 BEHAVIOURAL OBJECTIVES AND TAXONOMIES

This taxonomy has generated a lot of criticism, both constructive as well as uncharitable. Proponents of behavioural objectives such as Glasser (1962), Mager (1962), Lindvall (1964), Tyler (1964), Walbesser (1964), Krathwhol (1965), Gagne (1966), Popham (1968), emphasised the utility of behavioural objectives as indicators of direction of pupils' growth or intended learning outcomes. On the other hand, critics of behavioural objectives like Atkin (1963), Arnstine (1964), Eisner (1967), MacDonald (1973) argue that predetermined objectives hinder the development of the learner as he is forced to undergo an inflexible mode of learning focussed on the fixed goals which may or may not be achievable. Both these opposing views are sometimes polarised to the extent that curriculum developers like MacDonald (1973) and Stenhouse (1969) Director of Humanities Curriculum Project in UK feel that it is absurd to formulate objectives in advance. Objectives emerge at the end. On the other hand, Wynne Harlen (1973) Director of the Project, Science 5-13 preferred to develop a full-fledged booklet on 'Objectives in mind' for the guidance of teachers. To resolve this controversy on the role of objectives in curriculum development Peter Kelly (1973) takes middle-of-the-road position in his project, Nuffield. A-Level Biology, by treating objectives to begin with, only as hypotheses which are constructed on logical basis. These objectives during trial of the materials transform into formative objectives as these are under trial for their practicability. These objectives later on emerge as summative objectives when the curriculum is finally revised after implementation. Such objectives then become the real objectives of the curriculum.

Whatever position one may take regarding the place of objectives in curriculum development, it is important that, they be precisely stated and defined. This is recognised by the fact that during the sixties an increasing attention has beeen paid to the statement of objectives in behavioural terms to facilitate the evaluation of educational programmes as also to improve the validity of the measures used in such evaluative process. Mager (1962), Lindvall (1964), Tyler (1964), Walbesser (1964), Gagne (1966), Hasting (1966) and Metfessel and Michael (1969) are among those who seemed to hold that to express objectives in behavioural terms is the only way to describe and evaluate the curriculum development process as well as the end-product of curriculum.

Although there exists some difference of opinion regarding emphasis to be put on the specification of objectives in behavioural terms, there seems to be consensus as to the growing need for validating the postulates underlying Bloom's taxonomy. A number of efforts have been made in this direction to investigate empirically the assumptions underlying this taxonomy.

Space does not permit detailed account of each of such studies. Attempt is made here to refer to only selected and significant studies, particularly their findings and conclusions. Besides, the focus of this review would be more on the methodology used in those studies and the rationale used to measure the product (developed goals) or also the process (developmental goals) used. But for a few studies which can be counted on fingertips undertaken in India, most of the work in this field has been done in the USA. Reference to the other taxonomies which have emerged as a sequel to this taxonomy has also been made here. Some evidence is available on validation of taxonomy of Affective Domain. As far as taxonomy of psychomotor domain is concerned, the work is still in the stage of infancy.

3.2.2 STUDIES ABROAD

After the taxonomy (cognitive domain) was developed, it engendered a lot of interest among the curriculum developers and evaluators to use it. Some of the important studies which have direct bearing on the present investigation are given below :

Dunn and Turner (1959) using the physics content developed taxonomy type tests based on knowledge, application and understanding. The last objective in this study included the remaining four categories of objectives. Significant correlations were reported in this study.

McQuitty (1960) outlined and illustrated a rapid paper and pencil method for analysing the matrix of associations between people, tests, institutions or other objects to syndromes of successively higher orders—such as first into species, then genera, families, etc. Two methods of the version are described. One is rapid but somewhat approximate while the other is more complete but more laborious. Both versions can be realised in terms of computations contained in the original matrix. No additional computations are made and the only requirement is to rewrite the cell entries in the prescribed sequences.

McKeachie (1962) demonstrated in his study the use of different instructional methods for attainment of objectives at different levels in order of complexity. His study

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suggests that knowledge objective can be achieved both by lecture and discussion methods whereas higher objectives requiring practising of behaviour that can be achieved more easily by problem-solving approach.

McGuire (1963) studied the relationship among the different objectives in the field of medical studies. He investigated the inter-correlations of taxonomic level and found a transcendence of levels of the taxonomy.

Anderson (1964) developed taxonomy tests using Chemistry content on the first four categories of objectives, i.e., knowledge, comprehension, application and analysis. Using the factor analysis technique he found that knowledge and comprehension form one cluster while application and analysis formed another cluster.

Stoker and Kropp (1964) conducted a series of studies designed to investigate the empirical validity of the taxonomy. One of these studies dealt with two questions relating to the validation. Can judges agree on the cognitive process which an item is supposed to measure ? Can empirical evidence be gathered to support the imputed hierarchical structure ? The data were gathered from five raters who were asked to classify 36 multiple choice items on atomic structure equally divided over all the six categories, and 36 multiple choice and three free response items on another test on 'right size', nearly equally divided. Results show that raters do tend to categorise items in congruence with the category behaviours the items were intended to evoke. This, however, has no bearing on whether items do in fact, evoke the processes they were intended to evoke. The data supports in general the hierarchical structure of the taxonomy but for the possible misplacement of evaluation. Factor analysis failed to support the hypothesised structure of the taxonomy.

Krathwhol (1965) explored the possibility and necessity of developing objectives at various levels of generality and abstraction. Discussing the rationale this article suggests that the most general level of stating objectives is useful for programme planning ; intermediate level can be facilitated by the framework of taxonomy. Such an analysis has far greater implications, than the traditional opinion-oriented approach, as it would be a better and more researchable process.

Smith, A.B. (1965) examined the scalability of knowledge and comprehension level of taxonomy on a sample of 341 students in educational psychology. As reported inter-correlation matrix of knowledge and comprehension sub-level scores failed to form Gutman's Simplex. Thus the hierarchical structure of the first two categories as claimed in the taxonomy stood rejected.

Thomas, A.M. (1965) studied the first three categories of objectives. Analysis of results about the cumulativeness of taxonomy indicates that the three categories showed the general pattern of Gutman's Simplex, thereby supporting the assumptions of the taxonomy.

Kropp, Stoker and Bashaw (1966) in one of the most illuminative papers raised a number of issues and has indicated methodology to tackle them also, regarding validation of the taxonomy of educational objectives. In this paper some major problems concerning validation of taxonomy : cognitive domain, are raised which must be taken into account to get evidence of validity. The main problems include deciding on appropriate response measures, test format, observational conditions besides selecting or developing valid statistical methodology and model. Problems of internal and external evidence of validity are posed and suggestions are offered.

McQuitty (1966) devised a very simple method called the similarity analysis by reciprocal pairs. This method is applicable to both discrete and continuous data. This technique of analysis is now widely used in knowing the cumulative nature of the taxonomy of educational objectives.

Saunders' (1967) analysis of question papers and pattern of school examination reveals that majority of questions are only of memory type. According to him a minimum of one-third of the time allotted to questioning both in instruction and evaluation should be given to levels above memory. When questions are classified irrespective of instructional context and prior learning experiences, the coefficient of agreement among judges is likely to be low as it is difficult to know whether response to an item is given by utilising the corresponding cognitive level or by just mere recall or guess work. As such raters should categorise items on these lines.

Smith, R.B., (1968) used Kropp, Stoker's data and subjected the inter-correlations to the hierarchical syndrome analysis of McQuitty (1966). This study in general supported the hierarchical and cumulative nature of the taxonomy. Data were based on the use of four tests based on the taxonomy rationale. Each of these tests consisted of six subtests corresponding to the six classes of the taxonomy. Each test was based on a reading passage. One departure was that multiple choice items were used only in the case of first four categories while free response items were used in case of synthesis and evaluation objectives. Tests were administered to ninth through twelfth grade students, number being at least 750 at each level. In six of the sixteen matrices, the initial reciprocal pair consisted of 'Comprehension' and 'Application' subtest and in every case this reciprocal pair was then joined by the Analysis subtest. Of the six major classes of the taxonomy only the Knowledge and Evaluation categories were generally found to behave inconsistently with the theoretical formulations.

Heron (1971) as a result of review of the literature, concluded that 'some studies seem to indicate that by providing students with objectives achievement will be enhanced while the results of other studies indicate that no such advantage will accrue'. This study (Intermediate Science Curriculum Study) shows that knowledge of behavioural objectives in advance does enhance achievement of students of low ability. From this study it appears in objective based instruction, cognizance of objectives by students and teachers is important to develop different cognitive abilities.

Klopfer (1971), while discussing evaluation of learning in science has given altogether a different categorisation of objectives of science instruction. He has discussed 'Knowledge' and 'Comprehension' together as the first objective of science instruction followed by 'Processes of scientific enquiry', 'Seeing a problem and seeking ways to solve it', 'Interpreting data and formulating generalisations', and 'Building, testing and revising a theoretical model'. Last objective in this classification is 'Application of scientific knowledge and methods'. Besides these, cognitive objectives, manual skills, attitudes and interests, and orientation (comparable to appreciation) are also discussed. Two important departures are : (i) the clubbing together of 'knowledge' and 'comprehension' thereby taking both as complementary to each other ; and (ii) 'application' objective is listed at the top of all the cognitive objectives thereby pleading for the use of processes of enquiry as prerequisite to the development of the ability to apply scientific knowledge in unfamiliar situations.

Daniel Tanner (1972) in his small booklet on, 'Using behavioural objectives in the classroom', has pinpointed the limitations of the paper pencil tests in assessing the behavioural objectives in the classroom. He considers knowledge as the resource for further learning rather than as an end-product, because learning is not a terminal process. With reference to the tripartite taxonomies relating to cognitive, affective and psychomotor domains, he commented on the continuity and interdependence of the three domains. That is why he considers that the instructional objectives by Bloom and his associates reflect a logical rather than ecological classification which takes into account the arrangement of phenomena in interaction among themselves. It is, therefore, logical to conclude from this, that hierarchical learning is not like that of a vertical pyramid but like that of a food web.

Walbesser and Eisenberg (1972) have reviewed the research on behavioural objectives and learning hierarchies. As quoted by Dave (1976) Gagne observed 'Bloom's technique for defining objectives has been tried out in a number of universities with respect to achievement testing and evaluation programmes. Perhaps it is unfortunate that the "Evaluation" carried out by means of these procedures has not itself been evaluated in some controlled fashion'.

In the same report it is further commented that the literature offers cautious support to the hypothesis that providing the learner with information about expected learning outcomes affects his performance. The direction of the effect appears to be positive. The magnitude of the effect is, however, not clear. How much of the variance can be attributed to learner information about expected learning outcomes is not provided by the literature. These are further avenues for further investigations. In the present study the investigator has incorporated the idea of expected learning outcomes in experimental teaching as well as in the preparation of instructional materials.

As regards the behavioural objectives and the teacher the report comments : 'More research needs to be conducted on the potential relationship between behavioural objectives and the teacher before any clear direction is apparent. One hunch that emerges from the reported investigation is that teachers must be taught to use behavioural objectives in planning instruction and evaluation if they are to be used at all.' With reference to the learning hierarchies it is reported that

> 'The investigations of learning hierarchies concern themselves with the questions of positive transfer. Data analysis procedures first focussed on assessing the magnitude of positive transfer for one "hypothesis of learning dependencies", that is, one set of subordinate behaviours mediating to exactly one terminal behaviour. Strings of hypotheses of learning dependencies or "learning hierarchies" were then investigated for sequential or cumulative learning effects. Four procedures are currently available for learning hierarchies analysis : Gutman scale, Gagne, AAAS Commission on Science Education, Walbesser and Eisnerbert.'
>
> 'Item and measure statistics for criterion tests are rare. One reliability estimating procedure is available. How many criterion items to sample for estimating the acquisition of a given behaviour is not known. The effect of increasing the number of assessment tasks for a given behaviour upon decisions of presence or absence are not known. The effect of changing performance tasks to paper and pencil tasks are not known. Much work needs to be done before any clear direction is apparent for the item and the measure statistics associated with learning hierarchies and behavioural objectives.'

The above review published under the title 'Mathematics Education Information Report' does not include information regarding similar investigations carried out in respect of other subjects.

Arnold, Atwood and Rogers (1973) reported that level of questioning is significantly related to the level of response to the question, when questions were dichotomously classified as memory level and above memory level at the elementary stage. At the secondary stage the result indicates strong relationship between levels of teachers' questions and students' responses thereby indicating that when questions beyond memory level are asked, they act as an effective method for students to operate at cognitive level higher than memory.

At the secondary science level the result of this study indicates strong relationship between levels of teachers' questions and students' responses. Lack of significant differences between mean lapse time for memory and above memory level questions and the response appears unexpected and needs further investigation. It would have been more fruitful had there been an adequate number of questions which were asked at all the six levels of Bloom's Taxonomy to study the relationship between questions and response level for secondary science. This study highlights the use of objective-based questions at all levels in order to improve students' achievement on all those objectives.

Stedman (1973) working in the field of genetics administered 93 frame programme based on 23 behavioural objectives to 144 students from eight high school biology classes. Only four levels from Knowledge to Analysis were used in this study with 28 items, 7 for each level. Rationale for each item is given. Analysis shows 80% students responded to Knowledge and Comprehension and 50% to Application and Analysis indicating thereby a larger gap between Comprehension and Application. No significant difference between Knowledge and Comprehension or Application and Analysis was observed. Between Comprehension and Application it was significant beyond 0.05 level. The same was true for mental ability and motivation. It is reported that cumulative hierarchy appears to be erroneous. The hierarchy in the categories of the taxonomy may be acceptable only if hierarchy is viewed as progressing unevenly from low cognitive level to higher cognitive levels. Thus cognitive processes involved in moving from Comprehension to Application appear to be different from those between Knowledge and Comprehension or Application and Analysis.

Richard (1974) while discussing the model of learning hierarchies listed nine stages in his model as compared to seven stages in Gagne's model. The major feature in this model is the check on face validity of hierarchy by experienced teachers ; investigations of possible division of elements, the embedding of questions for elements in the learning programme and the use of a statistical test of hierarchical dependence which takes errors of measurement into account. These changes in methodology of hierarchical research should provide more soundly based answers to questions of the validity of learning hierarchies.

Russell (1974) researched the cross-cultural validity of learning hierarchy of graphical interpretation skills with 192 grade seven students in Australia and 200 indigenous grade 9 students in Papua, New Guinea. Both groups contained approximately equal number of male and female students, with mean age of 12.5 and 15.5 years, respectively for Australia and Papua, New Guinea. The learning hierarchy was constructed by logical task analysis and validated by means of comprehensive instructional and testing programme. Each pair of hierarchically related skills was tested for significance. The results indicate that the pattern of acquisition of interpretative skills was substantially the same for both groups of students, irrespective of their different cultural backgrounds, providing important cross-cultural evidence for the principle of hierarchical learning.

In the study by Victor (1974), in which 33 examiners from 18 schools of Lebanon, were given items to classify, no difference was reported to have been observed with respect to professional training, specialisation and status. It is only length of experience that has moderate positive correlation of 0.53. The pattern of teacher-made examination revealed about 72% Knowledge, 20% Comprehension, 7% Application questions and none on Analysis, Synthesis and Evaluation. Therefore, low correlalation among the raters does not necessarily indicate the poor quality of the items according to the investigator.

Clifford, and Sherman (1975) studied the effect of providing students with objectives, on achievement. It shows that knowledge of behavioural objectives in advance, by students does enhance achievement of low ability students. From this study it appears that in objective-based instruction, cognizance of objectives by students and teachers is important to develop different cognitive abilities.

Fair Brother (1975) found the reliability of teachers' judgment with respect to the two question papers of 40 items each in Physics (A) level course. These items represented the first four categories of the taxonomy and were given to teachers along with a reference note giving description of each category with illustrative items meant for continuous refer back to facilitate classification of items by them. The opinion of teachers has been correlated with the facility values for the items and the coefficients obtained, appear to support the Bloom's taxonomy. He reports that

> 'if any particular ability has not been developed, the student will not be able to answer those questions which test that ability. If an examination omits to test for any particular ability whether by accident or by design then using the Bloom's taxonomy should reveal this omission.'

Novetto (1975) discussed the importance of behavioural objectives and their validity through verbs. Giving a number of examples of the behavioural objectives followed by the test items, their relevance is criticised. It has been highlighted that validity of an item can be judged by observing the relevance of the directional words (action verb) like choose, define, etc., to the behavioural objectives. Examples pointing out the anomalies from the actual test material, are used to clarify.

Treffinger and Huber (1975) believe that 'Psychological principle of sound instructional planning can be applied productively to creative problem-solving courses and that students can benefit from such efforts. On the lines of Parnes (1967) the authors while planning the instructional programme developed specific instructional objectives to accompany the creative behaviour guidebook and workbook. This was followed by development of learning hierarchies. This attempts correlates the methodologies of creative problem-solving and instructional technology. This approach supports the viewpoint that for testing higher level objectives it is necessary that students are taught in accordance with the pre-determined specific objectives relating to the course of study.

3.2.3 STUDIES IN INDIA

Because of his association with the establishment of the Central Examination Unit, (now a part of the National Council of Educational Research and Training as Examination Reform Unit) under the All India Council for Secondary Education in 1958, Dr. Bloom's impact on the programme of examination reform is tangible in this country. The unit adopted the model of Objectives↔Learning Experiences↔ Evaluation↔Feedback. In one respect it deviated significantly. Instead of adopting the six-tier taxonomy, based its work on the three-tier classification of objectives i.e., Knowledge, Understanding and Application. The main work has been in the direction of objective-based testing which comprised construction and classification of test items in all the school subjects. In the field of biology itself the investigator has been engaged in the task of orienting paper setters, teachers and teacher educators in the technique of objective-based evaluation. A number of booklets and reports have been brought out as a sequel to these courses and orientation meets.

In all such materials validation of the three-tier taxonomy has been limited to raters' classification of items. There is always a controversy as to the agreement on the application items because of the differences in background that one assumes about the nature of learning experiences provided to the students. This is not unexpected as the teaching criterion varies from rater to rater. Nevertheless, this three-tier taxonomy did improve quality of questions and question papers of the different Boards of Secondary Education in India by making it obligatory for the paper-setters to provide for all these types of questions in the design of question papers.

Analysis of the question papers of various Secondary Education Boards clearly reveals that application questions are more difficult to attempt than those testing comprehension which in turn are more difficult than those on knowledge. As a result of this, scores on these three objectives go on decreasing as we proceed from knowledge to application. It is not uncommon to find that many times application items turn out to be mere recall items for a particular groups of students for the simple reason that due to previous acquaintance with the situation such items demand only knowledge of application of a certain principle rather than ability to apply that principle. It is, therefore, desirable in any study of validation of this type to ascertain whether the student really exercises the same mental processes to attempt a question that have been claimed by the author of that item. A preliminary attempt in this direction is made in this study and results are interesting from the point of view of student-generated hierarchy.

Pachauri (1971) analysed the data of Helgeson's work concerning relationship between concept of Force attainment and maturity as indicated by grade levels. This study in general supports the cumulatively hierarchical nature of the taxonomy, but not as conclusively as did the studies by Kropp and Stoker (1966) and Smith (1968).

Dave (1972) in his paper on 'developing a cognitive model of learning' made an attempt to integrate some theoretical approaches to cognitive learning and develop an integrated model which could be tried out in the classroom situation. While commenting on Bloom's taxonomy as an evaluation model which takes into account only the end-product of learning and ignores the process leading to that product, plea is made for the need to convert the evaluation model into a learning model. The strategy adopted is as under :

The Content Input × The Process = The Output

For testing the underlying assumptions null hypothesis models are given. This study highlights one important point, that unless a product (learning outcome) is purposefully developed its evaluation may not reflect true evidence on the assumptions being tested.

Dave and Anand (1973) investigated the empirical validity of educational objectives (Bloom) and related it to the medium of instruction of adolescents of Mysore State. In this study the data used consisted of achievement tests which were not constructed with specific objectives and behaviour outcomes in mind. To obviate this shortcoming a more objective and reliable system of classification of items into three categories of objectives was developed. Use of reference note for the rater and their orientation was made for classification of items. For analysis of results Friedman test of analysis of variance was used besides the techniques of Hierarchical Syndrome Analysis developed by McQuitty (1960, 1966). Overall results lend substantial support to the taxonomy. As reported, deviations from the theoretical predictions seem to arise from the artifact of test construction rather than from the fallacy of postulates. This study provides a useful hint regarding interpretation of evidence keeping in view the quality of test items used to get the evidence.

Dave, Prasad, *et. al.* (1974) prepared a set of five units representing a significant part of the major experimental project that was undertaken to evaluate the effectiveness of the physics resources material. A set of 30 items for each unit was prepared comprising 10, 13 and 7 items on Knowledge, Understanding and Application. Statistical information about the items reveals that simple recall items assumed to represent the low level learning turned out to be as difficult or more difficult than the understanding items, and even in certain cases more difficult than the application items. Likewise, a significant difference seems to exist between recall and recognition items. This information is quite interesting as we are concerned with the complexity of the mental processes.

Dave and Pattanayak (1974) in their project 'Improving language skills in the mother tongue' prepared a bridge course of 96 hours with the objective of developing five language skills, Listening Comprehension (LC), Listening and Note-taking Competence (LNC), Reading Comprehension (RC), Guided Composition (GC), Epitomising (EP), of the college entrants in the pre-university courses in Karnataka State. Use of pretest and post-test technique was made with the experimental and the control groups. One of their hypotheses was that 'Language skills are hierarchically related'. This was tested by using Friedmans' test of analysis by ranks and the McQuitty's Hierarchical Syndrome Analysis (1960, 1966). It is statistically demonstrated that

a. EP > LC > GC > LNC > RC

b. RC
RC+LNC
RC+LNC+GC
RC+LNC+GC+LC
RC+LNC+GC+LC+EP

This study brings in another issue of the relationship between language hierarchy and the content objective hierarchy. To what extent language acts as a barrier or accelerator for either development or for testing attainment on an objective, is an interesting problem.

One of the latest works done in this field in India is by Dave (1976). Besides the studies mentioned above Dave has brought out a report entitled 'Hierarchy in Cognitive Learning'. This research report is based on the same integrated approach as suggested earlier by him for developing a cognitive model of learning. In this study four hypotheses are formulated which relate to the hierarchical and cumulative nature of the taxonomy of educational objectives comprising of knowledge, understanding and application as also concerning the expected behaviour outcomes implied under each objective. Besides, the other experimental hypotheses were, that students taught by means of specially prepared physics resource material show greater acquisition of knowledge, develop better understanding and ability to apply than students taught with the help of the usual texts and the methods. The same is true of the expected behaviour outcomes implied under each objective. As reported, the data distribution was not normal and the theoretical assumptions underlying were not compatible with the concept of normality, and therefore, a series of non-parametric tests were used to test the tenability of the hypotheses. The findings support the hypothesis that Knowledge, Understanding and Application are hierarchically related. However, when data were separated analysed for this group, it did not support the hypothesis in the case of the control group thereby indicated clearly a difference between the process hierarchy (developmental goals) and the product hierarchy (developed goals). This highlights the need for deliberate efforts to develop these goals.

Another finding is that students taught with the help of physics resource material using both its content and methods showed greater acquisition of Knowledge with respect to all the units, better Understanding with respect to two units and better ability to apply with respect to one unit than those taught by usual text and methods. As far Expected Behaviour Outcomes (EBOs) data showed that there existed differences among different levels of learning but data did not support the cumulatively hierarchical nature of the EBOs. Data did indicate that Recognition did remain at the bottom and prediction at the apex in the hierarchical structure. According to the investigator it appeared that mental processes under 'K' form a predicted structure, i.e., Recall$>$Recognition whereas under 'U' and 'A' they do not form a particular pattern but form different clusters within each category, reflecting either the peculiar nature of content or weakness of the measuring tool.

3.3 OTHER TAXONOMIES

Besides the above-mentioned studies relating to taxonomy of cognitive domain, mention may be made here of other taxonomies which have come out as a sequel to this work.

Krathwhol (1964) and his associates devised another taxonomy of educational objectives : Affective Domain, on exactly similar assumptions as listed for the Bloom's taxonomy regarding cognitive domain. This taxonomy assumes that pattern involved in acquiring value moves from a very low level of awareness to the highest level of internalisation ; lowest level being, receiving. This category is subdivided into awareness, willingness to receive and controlled or selected attention. Second level category which deals with attitudes and values. It is subdivided into conceptualisation of a value, preference for a value and commitment. Next level is organisation which is subdivided into acceptance of a value and organisation of a value system. Fifth and at the highest level comes the category, characterisation. At this stage an individual acts consistently in accordance with the values to which they are already committed.

Lewy (1966) studied the empirical validity of the taxonomy of affective educational objectives developed by Krathwhol (1964). Three special fields included both in high school and college curricula were selected ; Mathematics, Reading and Music. Tests containing about 80 items at the taxonomic level of Receiving, Responding, Valuing and Organisation were constructed. The last category, 'Characterisation' was excluded due to difficulty of framing of the items. Each of these tests were administered to 200-300 high school and college students. Technique of factor analysis and inter-rater agreement were used in support of descriptive validity. Dynamic validity dealing with the internal structure of the model and structural relationships between the constructs of the model and other constructs. Findings support the taxonomy with respect to the subtests of Mathematics and Reading but not in the case of Music.

In the field of psychomotor domain much work is not undertaken. However, two taxonomies have been proposed after the publications of Bloom's (1956) and Krathwhol's (1964) taxonomies.

Simpson (1966) proposed the taxonomy for classification of Educational goals in psychomotor domain. According to this taxonomy the major categories are, set, guided response, mechanism and complex overt response. This domain is concerned with the development and use of the muscles and the body's ability to coordinate its movements.

In India R. H. Dave (1969) proposed a taxonomy of Educational Objectives ; Psychomotor Domain. This taxonomy is based on the concept of coordination which runs as a common thread in the entire range of growth. Behaviours include in this Taxonomy concern muscular action and require neuro-muscular action.

This Taxonomy consists of the following categories of objectives :

(i) Immitation which includes, 'Impulsion' and 'Overt repitition'.
(ii) Manipulation which includes, 'Following precautions', selection and fixation.
(iii) Precision which includes, 'Production' and 'Control'.
(iv) Articulation which includes, 'Sequence' and 'Harmony'.
(v) Naturalisation which includes, 'Automatism' and 'Interiorization'.

Gagne's (1971) six-category system of classification of objectives by types of learning is a taxonomy unlike the ones described earlier. In this taxonomy major verb is the key descriptor which identifies the kind of intellectual operations being carried out by the learner. To describe the requisite skill displayed by the learner by overt behaviours minor verbs are used. The six categories are Reinstating, Discriminating, Identifying, Classifying, Demonstrating and Generating.

Harrow (1972) proposed another taxonomy dividing the psychomotor domain into six major classification levels. These are Reflex movements, Basic fundamental movements, Perceptual abilities, Physical abilities, Skilled movements and Non-discursive communication. The taxonomy stresses the dependence of higher order skills on the previous development of lower order skills.

Steinaker and Bell (1975) have developed the model for classroom experience through the Experimental Taxonomy. The taxonomy is based on Gestalt approach and is called a functional tool by the authors. There are three components of this model. The first is the identification of the components like motivation, interaction, assimilation, replication and involvement. The second one is to develop curricular experience as a basis for evaluation. This step includes terminal performance, objectives, introduction, reinforcement, mastery sequence, strategies, skills and evaluation. The third and the last is the format for evaluation design. This taxonomy is, therefore, an attempt to integrate the various types of objectives irrespective of the domain as we see in the case of Bloom's or Krathwhol's taxonomies.

Apart from the taxonomies referred to above an up-to-date account of description and use of work of Guilford, Dave, Kitbier, Simpson, Harrow and the D. Hainaut's taxonomy is discussed by Landsheere (1977) in the International Review series.

3.4 SOME RECENT STUDIES

Although quite a few studies have been undertaken since the completion of this study undertaken by the author, yet there is hardly any study which deals directly with the empirical validation of Bloom's taxonomy of educational objectives. Nevertheless, following studies deal with various issues related to cognitive objectives are mentioned below :

An alternative to Bloom's taxonomy by Winn (1977), properties of Bloom's taxonomy by Seddon (1978), quantitative study of cognitive instructional level as related to pupil achievement in terms of Bloom's taxonomy by Farns (1978), higher cognitive questioning and critical reading by Newton (1978), designing essay questions for different levels of learning, using Bloom's taxonomy, by McDanial (1979), levels of processing analysis of Bloom's taxonomy, by Qunen (1981), reconstructing Bloom's taxonomy of educational objectives by Moor (1982), an analysis of six principles of economics testbooks using Bloom's taxonomy by Karnes (1983), a classification of ISIS programme using Bloom's cognitive taxonomy by Clevenstinc (1987) and 'towards asking the right questions' using Bloom's taxonomy by Kloos (1988), are some of the more recent studies reported in various educational journals.

3.5 EMERGING ISSUES

From the foregoing review of literature relating to the validation of the taxonomy of educational objectives it is quite evident that a lot of work still needs to be done to get evidence about the validity of this taxonomy of educational objectives. Some of the points that have emerged from these studies and need special attention of the investigators, are as under :

3.5.1 In India no work appeared to have been done as far as the postulate of 'learned' behaviour' is concerned, before this study was undertaken.

3.5.2 There was no evidence available in India about the empirical validity of this taxonomy on all the six objectives taken together, until this study was undertaken.

3.5.3 Except for Dave in most of the studies in India related to validation of taxonomy emphasis had been on the product aspect of behaviour which is assumed to have been developed as a result of teaching done normally without any planned and deliberate effort made for the same. The process aspect involving interaction of content and method of teaching was ignored in almost all of the studies. This aspect needed further probe to see the effect of process on the product.

3.5.4 Validity of students' responses on the test items was assumed without ascertaining the mental processes actually exercised by them. This was an area that had not yet been explored through empirical validation studies leading to the determination of student-generated hierarchy.

3.5.5 In most of these studies variable of course content was generally not considered essential for test construction since items were either selected from a test pool or taken from other existing sources. Alternatively, the items were framed by the test constructors on different concepts from different topics, to test different objectives using different content. Use of same concept for testing on all the six objectives was not tried in these studies.

3.5.6 Since validity of the items depends on the number of raters who classify an item likewise in one of the six categories, proper selection of raters, their orientation and illustrative material for their guidance had to be ensured to minimise the variance in their judgment, that may arise simply due to their ignorance or misinformation about the concept of various objectives which becomes the basis of categorisation of the items.

3.5.7 Format of the test items is another feature which appears to have some bearing on the responses of students. This might be true of those items which are supposed to evoke mental processes on higher objectives like those of 'Synthesis' and 'Evaluation'.

TO SUM UP

From the various studies mentioned above, one can identify various educational and psychological issues which are discussed by various authors. Educational issues are concerned with categorisation of educational objectives to facilitate communication while the psychological issues are concerned with ordering of the categories to be consistent with relevant and accepted principles and theories. According to Seddon (1978) it seems unlikely that any single taxonomy would ever provide a means of universal perfect understanding. Hence it would seem more relevant to find out which taxonomy is the best as a means of communication. He suggested that further experiment should compare the extent of the agreement between the judges using Bloom's taxonomy with taxonomies like those of Gagne (1963), Ebel (1965), Merril (1971).

On the question of validation of cumulative hierarchy, several of the techniques used were found to be inappropriate and the conclusion based on these techniques were, therefore, considered invalid. The most meaningful conclusion concerning the hierarchy is to be derived from Simplex Analysis of Kropp and Stoker (1966) and the

Multiple Regression Analysis of Madaus and his Associates (1973). The former technique was used by the author in his study.

From the above-mentioned studies it appears that validation of a taxonomy like that by Bloom, has to be undertaken keeping in view different angles. The most important is the role of content and its equalisation for using it as a medium to develop various abilities, categorised under various educational objectives. As such any hierarchy of objectives cannot be validated empirically unless content is equalised. Secondly, unless there is objective-based teaching for development of those abilities implied by various objectives, valid inferences cannot be drawn about the hierarchy because development of these abilities through teaching is the pre-requisite to testing for those abilities. Thirdly, use of product-responses alone, for validation will not serve the purpose unless compatibility of product-responses with the process-responses is established. Above all, it is necessary that whosoever makes judgement about the congruence of the product-responses with the process-responses implied in the objectives must also be a trained specialist in the use of taxonomies. An attempt was made in this empirical study to take into consideration all these basic considerations that are relevant to the validation procedure. It is in this context that development and use of objective-based unit plans and objective-based teaching-learning strategies were considered essential as pre-requisites for appraisal of learning-outcomes using objective-based tests developed on all the six categories of objectives listed in the Bloom's taxonomy.

4

4.0 GENESIS, OBJECTIVES AND THE PARADIGM

It need hardly be mentioned that in any research activity use of terms consistently with the same connotation is essential for effective communication. This is particularly important in a field of study like that of 'education' which being a developing discipline lacks exactitude of the natural sciences in assigning exact meaning to the terminology it adopts in explaining theoretical models. It is, therefore, desirable to clarify some of the technical terms which are used in this study. The main technical terms like Taxonomy, Objective, Hierarchy, Cumulativeness, Validity of Taxonomy are already clarified in the Chapter II. Some other terms like product response, process response, objective-based instruction and evaluation are discussed at appropriate places in their proper context.

4.1 GENESIS, NEED AND SIGNIFICANCE

Origin of development of Bloom's taxonomy (1956) can be traced to the 1948 meeting of the college examiners attending the American Psychological Association at Boston when for the first time the need was felt for a theoretical framework to facilitate communication among the examiners. Since then there has been increasing realisaion by educationists, curriculum workers and evaluators to use this taxonomy. Validation studies that followed this publication aroused a lot of interest in the field workers and curriculum specialists. There is hardly any full-fledged study undertaken in this country relating to empirical validation of this taxonomy (Cognitive Domain). All decisions are taken on ad hoc basis using opinion-oriented approach. Projection and maintenance of educational standards at various levels, planning and reorganisation of curricular experiences, grading of syllabi, sequencing of learning units, preparation of resource material, strategies of teaching, mode of evaluation, categorisation of tools and techniques of evaluation, grading of students and development of question banks, are some of the significant areas concerning teaching-learning process which usually have not been based on sound theoretical foundations. Taxonomy of educational objectives is one such, if validated, can provide the needed theoretical framework. Since there was no such theoretical framework available to suit the Indian context the need to validate this taxonomy could not be over-emphasised.

Besides theoretical considerations, the investigator was interested in understanding the teaching-learning process in the context of proposed hierarchy of learning as visualized in the Bloom's taxonomy. To what extent it could be possible to practise objective centered teaching in terms of attainability of intended outcomes of learning ? What could be the observable effects on students' learning if deliberate and planned effort is made to teach students for predetermined and specified intended behaviour in terms of expected learning outcomes ? Can objective-based teaching plans be developed and used effectively in actual classroom situation to reflect the desired mental processes ? Are there certain abilities under different objectives, which as compared to others are more amenable for transfer to new situations ? Is there correspondence between the mental process employed by the student in answering the question and the one projected by the investigator ? These were some of the crucial issues which were bothering the researcher for quite some time. Being interested in finding answers to these he was prompted to undertake the present investigation.

While proposing his model of cognitive learning Dave (1972) rightly pointed out the place of content and process as input variables and the product or the learning outcomes as the output variable. Importance of this model lies in appreciating the role of process variable which is considered responsible for a particular type of product vis-à-vis the development of abilities which we seek to judge as an end-product of learning. Thus evidence that accrues from this study would throw light on the impact of instructional objectives. Their modification and redefinition would become easier and would thereby lead to improvement in other components of curriculum as well.

Likewise, the cumulative hierarchy if established would go a long way to integrate teaching and testing by a shift in emphasis from content-based teaching to objective-based instruction, from disciplinary to integrative curriculum ; from arbitrary to heirarchical learning and from norm-referenced to criterion-referenced testing. Consequently opinion-oriented curriculum development would yield place to research-based curricula. This would particularly be useful in developing science curricula of the type 'Science for All' at present needed badly for liberal education as envisaged in the new pattern of education. Indeed the whole teaching-learning process can be revolutionised once the taxonomic model of hierarchical learning is duly validated and accepted.

4.2 BROAD OBJECTIVES OF THE STUDY

Keeping in view the need and significance of the study, the following objectives were set forth for this investigation :

4.2.1 To undertake an empirical validation of the taxonomy of educational objectives : Cognitive Domain.

4.2.2 To bring out the relationship among teaching, learning and evaluation in objective-centred instruction.

4.2.3 To determine the mental processes underlying test behaviour of students.

4.2.4 To determine the impact of learning on the cognitive growth of students.

In order to understand the intended outcomes of the study more clearly, the abovementioned four broad objectives were specified further, as under :

Objective 4.2.1

(i) To find out if the objectives categorised in the taxonomy are arranged in an hierarchical order.

(ii) To know whether the hierarchy as claimed in the taxonomy is cumulative.
(iii) To determine whether the cognitive processes designated in the taxonomy are learned behaviours.

Objective 4.2.2

(i) To develop such teaching-learning plans which reflect integral relationship among expected learning outcomes, learning experiences and evaluation.
(ii) To make evaluation an integral part of teaching-learning process.
(iii) To undertake objective-based instruction to develop the intended learning outcomes.
(iv) To judge the impact of objective-based instruction on the development of various abilities implied by different objectives.

Objective 4.2.3

(i) To identify the mental processes, students use in attempting an item.
(ii) To enable the students to verbalise the mental processes used by them.
(iii) To record the process response (expression of mental process) using open-ended or check-list technique.
(iv) To establish relationship between process response and the product response (answer).

Objective 4.2.4

(i) To developed concept-based sets of six items each forming the taxonomical test.
(ii) To ensure reasonable reliability and validity of the post-test.
(iii) To measure the cognitive growth of students in terms of six objectives.
(iv) To analyse, compare, relate and judge the students' performance in terms of their achievement.

4.3 SIGNIFICANT DEPARTURES FROM PREVIOUS INVESTIGATIONS

Before the problem is stated in the form of hypotheses, it would be desirable to discuss some of the significant points of departure from the usual investigations relating to construction of tests for validation of taxonomy.

It is a well-entrenched practice to develop achievement tests on the basis of normal probability curve because this characteristic (achievement) is considered to be normally distributed. This assumption may be doubtful. Garret (1973) has expressed his doubt in the following words :

> 'The striking similarity of obtained and probability distributions does not warrant the conclusion that all distributions of mental and physical traits which exhibit the bell-shaped form have necessarily arisen through the operation of dice or coin combinations. Moreover, when a psychologist usually constructs his test with the hypothesis of normality definitely in mind, the resulting symmetrical distribution is to be taken then, as evidence of the success of his efforts rather than as conclusive proof of the "normality of the trait being measured". "The selection of normal rather than some other type of curve is sufficiently warranted by the fact that this distribution generally does fit the data better, and is more useful. But the theoretical justification and the empirical use of the normal curve are two quite different matters.'

There is no reason why all distributions should approach the normal form. Thorndike (1913) has written : 'There is something arbitrary or mysterious about variability which makes the so-called normal type of distribution a necessity, or any more rational than any other sort, or even more to be expected on a prior grounds.'

4.3.1 In the present investigation it is viewed that academic achievement need not be normally distributed. It is assumed that achievement is not a single ability but a combination of many abilities like that of recall, interpretation, analysis, etc. Each of these abilities may have its own non-normal distribution although some of them may approximate normal distribution in relation to other curves of hierarchical levels. The test made in this study is in conformity with this assumption, thereby catering to all hierarchical abilities as envisaged in the taxonomic objectives.

4.3.2 Another departure regarding validation procedure made in this study is the assumption that if the learning experiences are relevant to the different hierarchical objectives, they stimulate the mental processes better to evoke the desired behaviours, than the traditional text-based routine learning experiences. This idea which has seldom been tried in this country for validation, has been put into practice in this study, although only on experimental basis on a limited sample. Specially designed instructional material and objective-centred teaching used in this experimental situation is discussed in details in the chapter on methodology of the investigation.

4.3.3 Still another departure is the ensuring of content equivalence. It means that content remaining the same it can be possible to use it as a vehicle to stimulate change at various levels of learning which is intended in the form of expected learning outcomes. The goal of teaching biology or for that matter any other subject, should, therefore, be to develop a set of abilities using content of respective subjects. Theoretically it would mean, that whatever content may be used, hierarchical structure of expected behavioural outcomes would remain the same. To put it operationally, it means that content can be manipulated in teaching to stimulate and develop the various mental processes leading to the attainment of objectives ranging from simple 'Knowledge' to the most complex 'Evaluation'. This should also be true for testing of students' performance on hierarchical objectives. This viewpoint is adopted in this study for development of taxonomy test in which for every concept a set of six test items based on the same biological concept but testing all the six hierarchical objectives of the taxonomy has been framed.

This does not, however, mean that subject content is merely an assortment of facts, concepts or principles and has no depth. In fact content itself can have its own hierarchy in the form of simple facts, concepts, generalisations, laws, etc. This means that for testing different objectives in hierarchy, content at any level may be used as a medium of testing. A specific fact, a concept or a generalisation may be selected and test items at all the six levels of the taxonomy can be constructed. In other words neutrality of content can be controlled by using the same concept or principle for items at all levels. Such an equivalence of content offsets the likely contamination of evidence which may occur due to the complexity of the content itself.

4.3.4 There is one more departure which in fact relates to the validity of students' responses. It is normally assumed that if a student attempts an item correctly the logical inference would be that the student employed the appropriate mental process which is supposed to have led him to arrive at the correct response. It was considered essential to determine an answer to the question as to how far this assumption holds good. Towards this end a procedure, the details of which are given in Chapter VI, was developed and data gathered from the experimental group.

The scope of the present study was therefore, not confined to validation of taxonomy by merely analysing the product responses the approach used in most of the studies. It also utilised the process-oriented approach which takes into account the need for the development of the specific abilities prior to making their appraisal.

4.4 HYPOTHESES FORMULATED

In view of the above-mentioned issues the principal hypothesis underlying this approach was that different categories of objectives as identified in the taxonomy of educational objectives : cognitive domain, form a cumulative hierarchy. However, for convenience of testing, further categorisation was considered appropriate and the following null hypotheses were set up :

H : 1 There is no significant difference among different levels of learning categorised in the taxonomy as Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation.

H : 2 Different objectives in the taxonomy do not form a cumulative hierarchy but are independent of each other.

H : 3 When taxonomy tests are administered to students at different grade levels (IX, X and XI) their achievement scores in all categories do not differ significantly.

H : 4 There is no significant difference in the acquisition of knowledge, comprehension, application, analysis, synthesis and evaluation between students taught with the help of objective-based instructional material using both its content and method and those who are taught by usual text and traditional methods.

H : 5 There is no significant difference between students who attempt an item correctly and those who do not, as far as the use of mental processes in attempting the items is concerned.

4.5 DELIMITATIONS

The present study was undertaken within the jurisdiction of Union Territory of Delhi. Data were collected from eight schools comprising of boys, girls and coeducational institutions under Private, Government, Central School Organisation and Public Schools Managements. In each of these schools data collection was confined to classes IX, X and XI. All these schools were higher secondary schools using English as medium of instruction for teaching the subject of biology. None of the schools could be selected from rural Delhi due to the non-availability of facility of teaching biology through the medium of English.

This study was limited to the subject of biology and the testing material was confined to five major physiological processes forming a part of classes IX and X (new pattern) Syllabus and also common to class XI Syllabus of the old pattern. In all, 812 students were tested : 321, 291 and 200 from classes IX, X and XI, respectively. For testing experimental hypotheses the study was confined to two sections of class IX of a school, one acting as an experimental and the other as a control group. Objective-based teaching was confined to only one section of class IX acting as experimental group. Teaching was done by the investigator in natural setting under the prevalent conditions, facilities and time table in the school in accordance with the prescribed teaching schedule.

4.6 THE PARADIGM OF THE STUDY

The paradigm of the study may be schematically represented as shown in Fig. 2

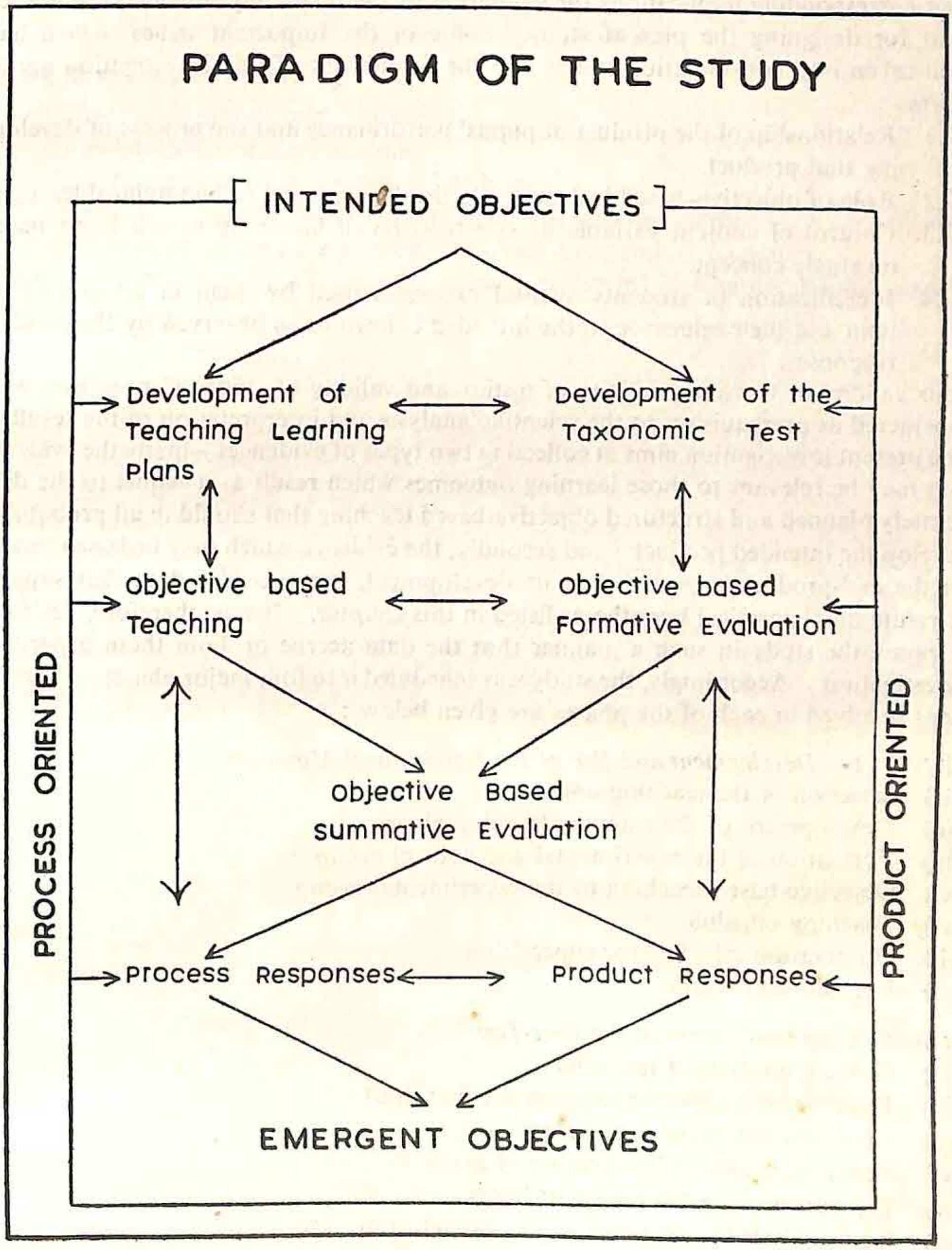


Fig. 2

to have an overall view of the conceptual framework which provided the needed rationale for the procedure adopted in the present study.

4.7 PROCEDURE ADOPTED

Methodology of this project was rooted in the foundation of the paradigm depicted in the Figure 2. Some of the significant issues raised in the previous pages and their corresponding implications for validation of the taxonomy provided the needed basis for designing the present study. Some of the important issues which had been taken into consideration to develop the framework of this investigation are as follows :

4.7.1 Relationship of the product of pupils' performance and the process of developing that product.
4.7.2 Role of objective-based instruction in the development of hierarchical learning.
4.7.3 Control of content variable by construction of hierarchy of test items based on single concept.
4.7.4 Identification of students' mental processes used by them in attempting an item and their relevance to the intended behaviour as observed by the product responses.

Thus validity of teaching, validity of testing and validity of students' responses were considered as prerequisites to the scientific analysis and interpretation of the results.

The present investigation aims at collecting two types of evidences—firstly the evidence that may be relevant to those learning outcomes which result as a sequel to the deliberately planned and structured objective-based teaching that should in all probability develop the intended product ; and secondly, the evidence which may be based merely on the end-product irrespective of its development, but provides data that support or refute the theoretical hypotheses listed in this chapter. It was, therefore, desirable to phase the study in such a manner that the data accrue on both these aspects of investigation. Accordingly, the study was scheduled into four major phases. Various steps involved in each of the phases are given below :

PHASE 1 : *Development and Use of the Instructional Materials*

(i) Selection of the teaching units
(ii) Development of the teaching-learning plans
(iii) Formation of the experimental and control group
(iv) Objective-based teaching to the experimental group
(v) Teaching schedule
(vi) Observation schedule for supervision
(vii) Formative evaluation

PHASE 2 : *Development of the Post-Test*

(i) Content analysis of the units
(ii) Framing of taxonomic items of the first draft
(iii) Classification of items by raters
(iv) Refinement and reclassification of items
(v) Try out of the second draft of items
(vi) Item analysis of 108 items of the second draft
(vii) Final test format of 60 items

PHASE 3 : *Administration, Scoring and Interpretation of the Test*

(i) Sample for the study
(ii) Administration on Sample A and Sample B
(iii) Special administration on Sample C
(iv) Scoring and tabulation of results
(v) Validity and reliability of the test

PHASE 4 : *Statistical Analysis and Interpretation of Data*

Testing of hypotheses regarding :

(i) Hierarchy of educational objectives
(ii) Cumulativeness of the taxonomy
(iii) Cognitive processes as learned behaviours
(iv) Impact of objective-based instruction on learning outcomes
(v) Correspondence between process responses and product responses

First phase is discussed in Chapter V ; second and third in Chapter VI and fourth phase in Chapter VII.

5

5.0 DEVELOPMENT AND USE OF TEACHING-LEARNING PLANS

As delineated in the last chapter, the first phase of the study was devoted to the preparation of objective-based instructional material and development of the intended learning outcomes. Therefore, the focus during this phase was on identification of the relevant units of teaching, development of teaching-learning plans, identification of the experimental and control groups, objective-based teaching to the experimental group in accordance with teaching schedule, ensuring effectiveness of teaching by the use of observation schedule by supervisors and adopting formative evaluation technique in teaching. Each of these aspects is described below :

5.1 SELECTION OF THE TEACHING UNITS

For instructional intervention in the experimental group, i.e., IX-A, selection of units of teaching had to be done very carefully. The following criteria were applied to ensure the relevance of the units for teaching and testing purposes :

5.1.1 Only those units were to be selected which are common to all the three classes, i.e., classes IX, X and XI so that at the end of the experiment a common test could be given to students of all the three classes.

5.1.2 Units selected were to form a composite block of the Syllabus so that sequencing could be possible for better teaching.

5.1.3 If some gap was there in the teaching sequence because of the syllabus, additional learning material was to be prepared and inserted at an appropriate place to facilitate learning.

5.1.4 One or two additional units were to be included to give practice in objective-based teaching in order to make the investigator as well as the students get used to the new approach to teacing and learning.

5.1.5 Keeping in view the time constraint for which classes could be placed at the disposal of the investigator the teaching load, i.e., the coverage of the syllabus had to be in accordance with the available time of one month or about 25 periods.

Considering the above-mentioned factors on the one hand and regular class time table for Biology on the other, seven topics were chosen for instruction and development of the test material. Although details of this are given in the second part of this section yet it may not be out of place to mention here that out of 24 concepts on which the test material was prepared to begin with, only 10 were retained at the end. It was on these ten concepts from five units that more attention was paid in objective-based teaching. The topics selected for teaching are given in Table 2 below :

TABLE 2

UNITS OF TEACHING

Sl. No.	Topics	Textbook Chapter Nos.
1.	Living things	II
2.	Levels of organisation	III
3.	Diffusion and osmosis	*not given
4.	Nutrition	XV
5.	Photosynthesis	XVI
6.	Respiration	XVII
7.	Internal transport	XVIII

This unit is given in the other textbooks and was considered essential for proper understanding of other topics.

Out of these units of teaching, the first two units were included to give the students the basic knowledge essential for the remaining units. The third unit was not there in their prescribed testbook but it was considered necessary to teach the principle of diffusion and osmosis so that they can later on appreciate the role of these processes in nutrition, ascent of sap, absorption and translocation of food materials. The other four units are already included in their courses of studies.

Because of the new pattern of schooling, popularly known as the 10+2, there was a lot of change in the syllabus. It was, therefore, necessary to select only those topics which were common to all the three classes, IX and X of the new pattern and XI of the old pattern. Thus apart from the first two topics used for practice, the remaining five topics are from the area of physiology which are taught in Class IX and tested at the end of Class XI in the Higher Secondary Examination.

5.2 DEVELOPMENT OF THE TEACHING-LEARNING PLANS

Selection of the units was followed by the development of the teaching plans. Since one of the hypotheses formulated relates to the effectiveness of the objective-based instruction in developing the abilities implied in the various objectives, it was incumbent to follow well-planned and deliberate teaching geared to the attainment of the instructional objectives of the units. It was, therefore, necessary to prepare unit plans of teaching keeping in view all those factors that have direct bearing on the issue of process-based product of learning.

One of the major purposes of such plans was to make an attempt to highlight the interdependence of unit-wise objectives, the learning experiences and the learning outcomes of the teaching-learning process. Since focus of these plans was on improved teaching, feedback mechanism was incorporated in the form of formative evaluation. Teaching plans thus prepared reflect the following emphases whereby it was ensured that whatever the product of learning was intended to be tested, must have, in all probability resulted from the teaching-learning efforts. Therefore, all the lesson plans prepared for this project aimed at :

5.2.1 Identifying the instructional objectives of the unit in terms of the taxonomy ranging from Knowledge to Evaluation.

5.2.2 Listing of specific objectives in terms of pupils' behaviour and content of the unit, in the form of expected learning outcomes.

5.2.3 Analysing the content of the unit in terms of major concepts which were to be developed and used as vehicle for attainment of the objectives stated in advance.

5.2.4 Providing the classroom interaction at various levels catering to the teacher-based and student-based activities.

5.2.5 Identifying the questions which could be used in teaching for diagnosis and getting feedback for instructional efficiency.

The rationale behind these teaching-learning plans is given in Annexure-A while a specimen lesson plan is given in Annexure-B.

The format of these teaching-learning plans reflect the following aspects :

(a) Overview of the unit
(b) Concepts to be developed
(c) Teaching-learning process which reflect
  (i) Specific objectives to be achieved
  (ii) Teacher-based activities
  (iii) Student-based activities
  (iv) Mode of formative evaluation
  (v) Review questions and assignments

How the process and product of learning are related to activities to realise the predetermined objectives is made clearer in the rationale given in Annexure-A.

5.3 FORMATION OF EXPERIMENTAL AND CONTROL GROUPS

To test the two experimental hypotheses, it was necessary to have two groups of students, an experimental and a control group. The local Central School at the Indian Institute of Technology, Campus was chosen for the purpose. Nearness, convenience, English as medium of instruction and cooperative attitude of the Principal and the biology teacher prompted the investigator to select this school in preference to other schools of Delhi. The two Sections A and B of class IX were adopted for this experiment—the Section A as experimental and Section B as control group.

On the basis of the opinions of the Biology teacher the two sections were taken to be equivalent in their background and academic achievement as far as the groups as a whole were considered. By and large these students came from the same type of homes and social and educational environments. Almost all of them came from the homes of the staff of Indian Institute of Technology and the National Council of Educational Research and Training. This view of equivalence was, however, later on confirmed by the test results on the six monthly examination, of both the Sections conducted by the school. Although validity or reliability of such an examination can be questioned, yet measuring tool being the same marking of the scripts having been done by the same teacher, who also taught both the Sections and the judgment of the biology teacher about the two Sections being the same, it seemed that sufficient evidence existed to declare the two Sections not different in their educational achievement, previous learning and home background.

Nevertheless, to be further sure about the equivalence of the two Sections, vocabulary and numerical ability tests prepared by the National Council of Educational Research and Training were administered to both the sections. Results of this test lent further evidence of the equivalence of the two groups. Statistical data for the same are discussed in the Chapter VII on statistical analysis. Section A was named as experimental where later on instructional intervention was done and Section B was taken as the control group. On the basis of the half-yearly test, the position of the two groups was found to be as shown in table 3.

TABLE 3

COMPARISON OF EXPERIMENTAL AND CONTROL GROUP

Groups	Experimental	Control
No. of students	42	41
Mean	69·89	70·17
Standard Deviation	11·20	12·20

No significance of difference in the means of two groups was found, thereby conforming the claimed equivalence of the two sections.

5.4 OBJECTIVE-BASED TEACHING TO EXPERIMENTAL GROUP

It was hypothesised that the use of objective-based material in objective-centred teaching leads to a better development of various abilities than the traditional methods. Keeping in view the purpose of the study, an attempt was made with the help of these plans, to develop in the students the abilities to recall, comprehend, apply, analyse, synthesise and evaluate. It is indeed a difficult task to identify a particular strategy of teaching which may help to develop all these abilities in the students. Nor is it possible to stick to any one particular theory of teaching or learning which could be followed for developing plans for teaching and for teaching itself. Study of literature, as discussed in Chapter III, however, reveals some important components which no model of teaching or learning seems to contradict. These major components formed the basis of some of the instructional interventions which were made in the strategy of teaching for development of higher objectives or abilities. The following instructional interventions were made accordingly :

5.4.1 Students were made aware of the accepted learning outcomes. For this, these intended learning outcomes were introduced at the introductory stage of the lesson in the classroom. Something like this was communicated. 'We are going to study today the food manufacturing process in plants and it is expected that as a result of learning this unit you would be able to

(i) recall the historical background of photosynthetic process.
(ii) comprehend the mechanism of photosynthesis.
(iii) apply, analyse, evaluate ....'

5.4.2 It was ensured that students had mastered the basic concepts considered as prerequisite to the learning of new concepts in the same unit of teaching or the one that follows. This was done sometimes as a part of introductory testing of previous knowledge and sometimes as a part of remedial work which had to be taken occasionally to fill up the gaps found as a sequel to unit testing.

5.4.3 Depending upon the nature of content and the level of instructional objective(s) to be achieved, different methods of teaching a concept were used ranging from simple exposition or narration to completely inquiry approach.

5.4.4 Effort was made to see that as far as possible, problem-solving approach is adopted so that students are made to confront the situations which require students' ability to apply, analyse, synthesise or evaluate.

5.4.5 Deliberate attempt was made to involve the students to the maximum extent in the discussion, demonstrations and even in the simple description of the experimental procedures, thereby ensuring the needed index of involvement depending upon the intended-learning outcomes.

5.4.6 Tried to use the most appropriate media of learning, relevant to the expected learning outcomes. This ranged from the real things like the experiment setup or a live specimen to the simple spoken words or oral questioning.

5.4.7 Different modes of learning were used during classroom teaching depending upon the predetermined specific objectives as listed in the teaching plans. These modes ranged from the complete domination by the teacher ; as in the case of imparting factual information, to the self-learning by students as in the case of certain situations involving self-questioning and self-finding of the information. This generally happened only when a particular problematic situation was posed and students' questions dominated the situation.

5.4.8 Since studies by Saunders (1967) and others have shown that questions testing higher level abilities promote higher level learning, special effort was made to use in teaching the questions at all the six levels of the taxonomy. These questions were used as a teaching device for testing different abilities ranging from mere recall to that of evaluation. This technique proved to be the most effective and usable in objective-based teaching.

5.4.9 Used home assignments which involved use of questions based on higher level objectives.

5.4.10 Care was taken to report pupils' performance on those assignments and classroom questions immediately after so as to provide immediate regular feedback to the students and for reinforcement of learning.

Various steps taken towards improved instruction were based on the following assumptions :

(i) If attainment of instructional objectives in terms of pupils' behaviours (mental abilities) is made the goal of teaching-learning process, a clear direction is provided for pupils' growth and meaningfulness to the teaching-learning process.

(ii) If learning outcomes of a unit are stated clearly in terms of expected pupils' behaviours, a sound basis for teaching and testing is provided.

(iii) If learning experiences, relevant to expected learning outcomes are provided, they promote better learning.

(iv) Gap between intended and actual learning outcomes is inversely proportional to the quality of learning experiences provided in terms of objective-centered teaching.
(v) Interaction between method, material and mode-media does have an impact on the effectiveness and intensity of learning experiences.
(vi) The more is the interaction involving pupil-dominated activities the more it facilitates the attainment of higher level of learning identified as application, analysis, synthesis and evaluation.

5.5 TEACHING SCHEDULE

Experimental group was taught by the investigator while the control group was taught by the equally qualified regular post-graduate class teacher of Biology having good experience of teaching the subject. However, the first two topics were taught by the investigator to both the sections which enabled the investigator to know their educational antecedents and provide the necessary background for students of both the sections. Thereafter, the experimental group was taught by the investigator and the control group was taught as usual by the school teacher. She was asked to do her best in teaching her control group. To keep to the schedule, teaching was done in both the groups according to the prescribed timetable which was neither favourable nor unfavourable to either of the groups. In fact the experimental group was a little handicapped due to inability of the researcher to procure sometimes the needed equipment and specimens for demonstration purposes besides the lack of rapport with students. Thus on the basis of the above-mentioned facts about the students' antecedants and availability of the facilities, both the Sections of Class IX could be said to have differed only in the transactions that followed as a result of the classroom interventions made by the investigator as stated above. Indeed if there was any advantage it was in favour of the control group due to better rapport with the students.

One handicap for both the sections was, however, the lack of motivation to learn some of the topics which were supposed to be taught in the following term rather than in the term in which this experiment was conducted. To overcome this difficulty it was possible with the cooperation of the teacher of Biology to declare in advance that students' achievement on these units would also be considered for their assessment on the units taught. This was enough to provide motivation to the students to attend classes regularly and with seriousness.

In all, 26 periods were taken to cover the topics included in the scheme of teaching. After each topic was taught, its review was undertaken to have a sort of diagnosis of pupils' difficulties if any, and judge the efficiency of the instructional efforts. Therefore, out of a total of 26 teaching periods, twenty were used for developmental teaching while the remaining six were devoted to diagnostic teaching and review. Topic-wise details are given in Table 3 :

Total time spent on instruction was about 15 hours. Since Biology teacher teaching the control group could not finish the prescribed units along with the experimental group due to practical examinations of students of Class X and other official duties she was forced to discontinue teaching for some time. But it was in a way advantageous to the students of the control group who could get more time for assimilation

TABLE 4

UNIT-WISE TIME FOR TEACHING AND REVIEW

Sl. No.	Topics	Teaching Periods	Review Periods	Total
1.	Living organisms	1	0	1
2.	Organisational levels	1	0	1
3.	Diffusion/osmosis	2	1	3
4.	Nutrition	3	1	4
5.	Photosynthesis	6	2	8
6.	Respiration	3	1	4
7.	Internal transport	4	1	5
	Total	20	6	26

of what had been learnt earlier by them. Apart from that, another advantage that accrued to these students was that by the time their course was over after renewed teaching, the testing had to be done immediately because the students of Classes X and XI, who were also to be examined on the same test, had to leave the school for preparatory holidays.

On the other hand the students of the experimental group were left to themselves for about two weeks and the investigator could not get any opportunity to meet that group even once to revise what was taught to them earlier. Indeed they were preparing for the final school examination which did not include those five topics on physiology. As such the experimental group can be said to have been rather in a disadvantageous position compared to the control group.

5.6 OBSERVATION SCHEDULE FOR SUPERVISION

Validity of objective-based teaching cannot be limited to the preparation of objective-based teaching plans and the principles listed under the previous heading of objective-based instruction. It is also important to note whether or not in actual classroom instruction the investigator is able to translate the unit plan or not. For this purpose, it was proposed to get the actual teaching observed by some one who had the experience of observation of lessons besides having a clear concept of the rationale underlying objective-based instruction. Two observers—one Professor of Education (Science) and another a Reader in Biology were selected for the purpose. Both have had long experience of observing lessons in teaching practice at one of the Regional Colleges of Education. They were also involved in finalisation of lesson plans. Both of them turn by turn observed two to three lessons in the beginning and made valuable suggestions.

To objectify observers' subjective judgments, an observation schedule was developed for the purpose. It consisted of a sheet of paper with three parts, namely, the listing of six criteria for improved teaching ; listing against each criterion the statements indicating the evidence of having used the criterion and the third part for rating by the observer on a three-point scale. This schedule (Annexure : C) was prepared keeping in view the components of objective-based instruction and its practicability aspect. This was finalised with the help of three of researchers' colleagues in Biology working in different departments of the National Council of Educational Research and Training and having good experience in evaluation.

A similar procedure was adopted in the preparation and finalisation of the teaching plans. Cooperation of additional three to five Biology teachers was secured. These teachers had good experience of developing teaching units in many of the workshops conducted by the investigator in the field of curriculum and evaluation.

Although only a few observations were made by the observers, it did help the investigator to improve teaching by taking into cognizance the aspects ignored while teaching. The researcher does not hesitate to admit that it was well-nigh impossible to make use of all the criteria to the desired extent in all the lessons. The things of which he was always conscious and deliberately trying to invoke were the announcement of the expected learning outcomes at the introductory stage of the lesson, avoid factual details and resort to excessive use of questions beyond memory level, ranging from interpretation to judgment making. Thus index of students' involvement by adopting problem-solving approach was one of the major focus of instructional strategy.

5.7 FORMATIVE EVALUATION

As pointed earlier, improved teaching did not end only with the measurement of students' learning but also aimed at improvement of their learning. As such, evaluation was made an integral part of the teaching-learning process, since this evaluation was mainly concerned with the diagnosis and feedback of the evidence and not with the grading of students it could be termed as formative. This was done as a continuous sort of assessment of students' learning through continual questioning, encouraging students to raise questions, posing problems relating to the learning situations and by observing students' responses in the classroom. As a part of formative evaluation, some non-traditional assignments were also given which besides serving as reinforcement devices did provide useful information as a part of formative evaluation. Such assignments were framed to test students' ability to interpret, reorganise, apply, analyse, synthesise, or evaluate.

Thus in the first phase of the study, deliberate attempt was made to emphasise the process or developmental goals in order to enable students to attain product goals. Formation of experimental and control group, selection of the units of teaching, developing rationale for teaching, treatment of the experimental group with the help of detailed objective-based teaching plans and observation of lessons by expert supervisors were the major tasks accomplished in this phase of work. A post-test of a special type was developed to collect the needed evidence to find out the extent to which the objective-based instruction had its impact. The details about construction, administration, scoring, validity and reliability of that test are discussed in the chapter that follows.

ANNEXURE : A

THEORETICAL RATIONALE FOR OBJECTIVE-BASED TEACHING

Expected learning Outcomes	Learning Experiences		Formative Evaluation
Specific Objectives (*a*)	Teacher-Centered Activities (*b*)	Student-Centered Activities (*c*)	Questions for Diagnosis and Feedback (*d*)
	Teacher-Directed Learning		
1.0 *Knowledge*			
1.1 Knowledge of specifics 1.2 Knowledge of ways and means of dealing with specifics 1.3 Knowledge of universals and abstractions	A. Providing reference for study B. Telling, narrating or lecturing C. Explaining D. Demonstrating E. Using teaching aids F. Knowledge-based questioning	(a) Locating information (b) Taking notes (c) Listening and reproducing (d) Responding and answering questions (e) Observing and recording (f) Preparing charts, models, apparatuses (g) Raising questions	(i) Use of information-based questions (ii) Scrutiny of text-book-based assignments (iii) Observation of practical work (iv) Assessment of students' products, e.g., charts, etc.

Teacher-Dominated Learning

(a)	*(b)*	*(c)*	*(d)*
2.0 *Comprehension*			
2.1 Translation 2.2 Interpretation 2.3 Extrapolation	A. Demonstration-cum-discussion B. Teacher-Pupil discussion C. Explanation D. Illustrations and examples E. Summarisation F. Comprehension-based questioning G. Clarifying the issues raised	(a) Participating in demonstrations and discussions	(i) Posing questions to test their ability to translate, interpret and extrapolate (ii) Using graphs and data for students to read, represent or extend (iii) Asking pupil to classify the facts, data, etc.

Teacher-Guided Learning

(*a*)	(*b*)	(*c*)	(*d*)
3.0 *Application*	A. Posing problem involving new situation B. Assisting pupils to recall the relevant concept/principle C. Guiding investigations/projects D. Conducting discussions in tutorials E. Providing data for pupils to draw conclusions F. Putting application-based questions	(a) Identifying Principles underlying the problem (b) Recalling the relevant information and the concepts related to the problem (c) Devising experiments and projects (d) Establishing new relationships between the cause and effect (e) Reasoning to support inference, conclusion or a generalisation (f) Making predictions from the given or observed data	(i) Providing unfamiliar situations for pupils to recognise the problem (ii) Asking pupil to cite illustrations involving the same concepts/principles (iii) Observation of practical work (iv) Asking questions testing pupils ability to apply

Pupil-Guided Learning

(*a*)	(*b*)	(*c*)	(*d*)
4.0 *Analysis*			
4.1 Analysis of elements 4.2 Analysis of relationships 4.3 Analysis of organisational principles	A. Posing unfamiliar problems for class and guiding discussions by students B. Assisting pupils to recall the relevant to principle/concepts to and use it to establish relationship with the various components C. Guiding discussions through sequential qestions D. Providing facts conclusions and generalisation for students to identify assumptions, relationships and the underlying principles. E. Organising small discussion groups or tutorials and introducing problems for students to solve	(a) Identify various steps or stages involved in the given problem (b) Relate the different components or elements in terms of their relevance to the underlying principle (c) Asking questions for classification and shifting the relevant from the irrelevant, known and the unknown elements, concepts, facts, etc (d) Accepting or rejecting the probable relationship on the basis of known theoretical structure (e) Identify the assumptions, relationships and underlying principles in a given communication (f) Participating in small discussion groups to thrash out issues	(i) Original situation is given for students to identify the relevant concepts (ii) Conclusions are given for pupils to identify conditions under which these conclusions are valid or logical (iii) Different, facts, concepts, principles or data are given for pupils to find relationships among them (iv) Using questions testing analysis of elements, relationships and organisational principles

Pupil-Dominated Learning

(*a*)	(*b*)	(*c*)	(*d*)
5.0 *Synthesis* 5.1 Production of a unique communication 5.2 Production of a plan or a set of operations 5.3 Proposing hypothesis or a set of abstract relations	A. Presentation of a new problem providing a set of data B. Using sequential questions for students to express, restate or reorganise the data in a different manner using a new untaught methodology C. Asking for an alternative solution to test a given hypothesis D. Providing data about an unfamiliar problem for students to suggest hypothesis E. Counter-questioning for proper analysis and propose alternative hypothesis, procedures and designs to solve a novel problem F. Make statements or situations involving analysis and synthesis	(a) Identify the main principle or concept underlying (b) Use the underlying concepts, principles to analyse different components and their relationship (c) Establish cause and effect-relationship between the known and unknown (d) Sift relevant and irrelevant facts (e) Counter question for proper analysis (f) Propose alternative hypotheses, procedures and designs to solve a novel problem (g) Make statements or devise situations involving analysis and synthesis	(i) Use of questions testing the three aspects of synthesis (ii) Providing hints on a problem up to the analysis step and asking students to fill up the last gap (iii) Asking students to identify the relevant hypothesis or experimental procedure suggested by the teacher relating to a new problem posed to pupils

(a)	*(b)*	*(c)*	*(d)*
6.0 *Evaluation*			
6.1 Judging in terms of internal evidence 6.2 Judging in terms of external evidence	A. A new problem is posed and by means of sequential questions evidence is sought up to the synthesis level. This is followed by questioning related to justification of the conclusions, procedure, design, hypothesis, etc B. Provides a number of statements giving evidence, conclusions, procedure and data in different situations for students to judge the veracity of these statements C. Providing definite criteria, statements or an evidence is given for students to judge whether it is correct/justified/unjustified or contradicts the given data D. Evaluation (Level of Taxonomy)-based questioning	(a) They judge the extent to which generalisations, procedures, design, etc., are consistent or logical with known facts or principles (b) They point out logical fallacies, inconsistencies in the given statements, data, conclusions etc., and give reasons, for the same (c) Identify the correct and incorrect statements on the basis of given data, and criteria, if any (d) Reason out the responses that they give to judge a statement evidence, conclusion, etc., as logical or illogical, adequate or irrelevant (e) Put questions at evaluation level	(i) Such questions are asked that pupils have to find out, the adequacy, validity or logic about the evidence that is given as an outcome of an experiment or a scientific phenomenon (ii) Identify the criteria of judging a statement or given a criterion judge the given statements. Question like the following are output (iii) Is this conclusion logical ? If not, why ? If yes, why ? (iv) What is the fallacy in this statement ? (v) Does the evidence lead to the conclusion drawn ? (vi) Are conclusion and evidence both valid ? (vii) Is the evidence given adequate ? If not, what more is required ? (viii) Will this experiment serve the purpose ? If not, why ?

ANNEXURE : B

OBJECTIVE-BASED TEACHING-LEARNING PLANS

Based on the five selected Units from the prescribed syllabus the teaching-learning plans were prepared in accordance with the theoretical rationale given on pages 50-55. These plans were prepared on the five units of teaching with following sequence :

Units of Teaching

UNIT : 1 DIFFUSION, OSMOSIS AND PLASMOLYSIS
UNIT : 2 NUTRITION
UNIT : 3 PHOTOSYNTHESIS
UNIT : 4 RESPIRATION
UNIT : 5 INTERNAL TRANSPORT

Sample Unit plan on one of these five units of teaching is given hereinafter to indicate the objective-based plan of teaching.

SAMPLE UNIT PLAN FOR TEACHING

PHOTOSYNTHESIS

Class : IX, Periods : 6+2

1. OVER-VIEW

'All flesh is grass.' This saying is quite appropriate if we understand the process of photosynthesis which is unique to plants. It is the only process of trapping the solar energy into other forms of utilizable form of energy. Conversion of solar energy into chemical energy in the form of oxidisable food is due to the photosynthesis of the green parts of the plants especially the leaf which is the main photosynthetic organ. It is here that pupils may be made to realize that this is the only process through which energy become available to all heterotrophs. How is food manufactured from the simple substances like carbon dioxide and water with the help of chlorophyll present in the chloroplast of the leaves gives an idea of link between the living and the non-living world, established by this process.

Magnitude of photosynthetic activities for food supplies should be highlighted while teaching this unit. New ventures to explore plant wealth of the seas to meet the increasing demand of the population may be told. This unit provides good opportunities for stressing themes like complementarity of structure and function, homeostasis, adaptation and molecular nature of the living process.

The theme of the unit can be mapped into the following lessons :

1.1 Introduction to photosynthesis, site of photosynthesis and review of anatomy of leaf.
1.2 Photosynthetic raw-material and necessity of carbon dioxide.
1.3 Role of light and chlorophyll in photosynthesis—law of limiting factors.
1.4 Photosynthesis process : light reactions.
1.5 Photosynthesis process : dark reactions.

2. CONCEPTS TO BE DEVELOPED

2.1 Many of the present energy sources are derived from the conversion of solar energy through the process of photosynthesis.
2.2 Leaves are the major organs where the entire process of photosynthesis takes place but other green parts of the plants also photosynthesise.
2.3 Internal structure of leaf is related to its photosynthetic functions.
2.4 The chloroplasts contain the pigment called chlorophyll and act as a seat of photosynthesis.
2.5 Carbon dioxide and water are two basic raw-materials needed in photosynthesis while enzymes and other organic molecules also play an important part in this process.
2.6 Light energy from the sun is absorbed by the green pigments and converted into chemical energy.
2.7 The process of photosynthesis involves physico-chemical process which may be grouped into two categories :
    (i) Light reactions in which water is split-up.
    (ii) Dark reactions in which carbon dioxide is fixed.
2.8 Oxygen is evolved during photosynthesis and is released by the plants into the atmosphere.

EXPECTED LEARNING OUTCOMES	LEARNING EXPERIENCES		FORMATIVE EVALUATION
Specific Objectives (*a*)	(Teacher-Centered Activities) (*b*)	(Student-Centered Activities) (*c*)	(Questions for diagnosis and feedback) (*d*)
1.0 KNOWLEDGE :	The Teacher :	The Pupils :	
The pupil acquires the knowledge of 1.1 significance of photosynthesis 1.2 photosynthetic organ 1.3 factors and raw materials related to photosynthesis. 1.4 mechanism of photosynthesis.	A. Pretests on leaf structure and functions. B. Introduces topic through van Helmont twig experiment or case history of the topic. C. Makes advance preparation for demonstrating the role of light, chlorophyll and CO_2. D. Provides references for studying. E. Provides examples of photosynthesis products like—vegetables, crops, seeds and asks pupils' to cite more examples from their daily life. F. Describes the role of CO_2, H_2O, chlorophyll and light in this process. G. Explains the steps involved in the photophase and dark-phase with the help of a chart.	(a) Recall the anatomy of leaf. (b) Study the references and prepare a case history of the development of concept of photosynthesis. (c) Give examples of photosynthetic products from daily life. (d) Note down the salient features of the factors affecting photosynthesis. (e) Write an account of the various steps involved in the mechanism of photosynthesis.	(i) Which tissue of the leaf contains chloroplast ? (ii) What is the function of guard cells ? (iii) Of what use are the inter-cellular spaces found in spongy tissue ? (iv) Give one example each of photosynthetic product of remote past, immediate past- and present-day. (v) Which factor affects the splitting of water during photosynthesis ? (vi) List various steps involved in the process of photosynthesis, in order. (vii) Which of the steps in (vi) do not require light ?

2.0 COMPREHENSION

The Pupil

(a)	(b)	(c)	(d)
2.1 Translates technical a. terms like A.D.P., A.T.P., N.A.D.P., N.A.D.P.H. into verbal form. b. represent the light and dark reactions in the form of schematic diagram.	A. Tells the formulae of the different compounds used and their equivalents. B. Provides the necessary hint to prepare a schematic chart showing Chemistry of photosynthesis. C. Demonstrates the variegated leaf experiment to show the presence of chlorophyll essential for photosynthesis.	(a) Pick up from the text-book the new technical terms and compound and write them in verbal form as well as in terms of abbreviated form. (b) Prepare a schematic chart depicting separately the various steps involved in light and dark reactions.	(i) Give verbal equivalents of A.T.P. & N.A.D.P. (ii) Write the following in abbreviated form : Adenosine diphosphate Niacin adenine dinucleotide phosphate. (iii) What is the first stable product of photosynthesis and in which phase it is produced ?
2.2 Interprets the a. observations related to veriegated leaf experiment, Molls' experiment and bubble experiment of evolution of oxygen. b. draws diagrams of the experimental setup. c. reads and draws graphs on limiting factors.	D. Discusses with pupils the need for variegated leaf and the precautions to be taken for boiling the leaf with alcohol. E. Explains that starch is the first insoluble product of photosynthesis and not glucose which is soluble.	(c) Participate in the conduct of experiment (d) Draw diagram of the setup. (e) Pose questions like the following : (i) Why do we boil leaf in water ? (ii) Why do we not take leaf which is completely green ? (iii) Why does pigment not come out on boiling with water ?	(iv) What is the purpose of boiling leaf in alcohol ? (v) Why do we test for starch in photosynthesis when the end-product is glucose ? (vi) When only certain portions of the leaf turn brown with iodine test, what does this indicate about the other parts ?

(*a*)	(*b*)	(*c*)	(*d*)
2.3 Extrapolates the effect of CO_2, light and temperature on the rate of photosynthesis.	F. Demonstrates light screen experiment to show the effect of light on photosynthesis. 4 days advance preparation for depleting of starch is needed and enough number of screens be prepared for students. G. Highlights that complete role of chlorophyll is not understood as yet to emphasise need for suspended judgment. H. Demonstrates likewise the Moll's Experiment to show the effect of CO_2 on photosynthesis. I. Explains the relationship of CO_2, light and temperature with the help of a graph. J. Provides situation for students to find the trend of photosynthetic rate on increasing the light intensity and CO_2 concentration.	(f) A group of students do this experiment. (g) Make note of the various techniques used, observations made and of recorded. (h) Why do we keep the plant in dark ? (i) Why screens are not put on all leaves ? (j) Studies and observes the demonstration. (k) Draw diagram of the experimental setup. (l) What is the cause of increase in rate of photosynthesis when light intensity increases ? (m) Can we expect the same results in artificial light ?	(vii) What is the purpose of keeping the green plant in dark for such a long time (35 hours). (viii) Where does the plant get food from during this period ? (ix) Why were plants exposed to light after putting screens ? (x) What does this experiment (Moll's) demonstrates ? (xi) Why do we keep half the leaf outside the bottle ? (xii) What is the function of KOH kept inside the bottle ? (xiii) What is meant by law of limiting factors ? (xiv) What type of graph would it be if there is further increase in CO_2 concentration ? (A graph is given).

(*d*)	(*b*)	(*c*)	(*d*)
3.0 APPLICATION The Pupil			
3.1 Establishes relation-ship between various leaf structures and their relation to photosynthetic activities.	A. Provides a prepared slide of the cross-section of leaf. B. By means of question like the ones given below or in the last column enables the pupil to observe the structure of leaf under the high power of the microscope, as a light absorber, water supplier and as absorber of carbon dioxide. i. What is the advantage of thin flat blades of leaves for photosynthesis ? ii. Does arrangement of leaves on the stem in any way related to photosynthetic capacity of the plant ?	(a) Observe the given slide and try to relate the different structures to various types of photosynthetic activities. (b) Pose questions for clarification of function of leaf as light absorber, water supplier and CO_2 absorber. (c) Respond to questions given in the last column.	(i) What type of cells contain chloroplast ? (ii) If palisade cells were located deep down instead of near the upper surface what difference it would have made from the point of view of leaf as light absorber ? (iii) How veins and midribs of a leaf are related to the photosynthetic activity ? (iv) In what way a thick cuticle helps to control the photosynthetic activity of the cells ? (v) How are arrangement of stomata, spongy tissue and carbon dioxide absorption related ? (vi) If number of stomata in a leaf are drastically reduced what effect it will have on its photosynthetic activity ?

(a)	*(b)*	*(c)*	*(d)*
3.2 Reasons for a using the variegated leaf water plants, KOH, boiling with alcohol and other experimental controls for conducting various experiments. b fixation of CO_2 in the absence of light. c evolution of oxygen from water and not from CO_2.	Poses problems like the following related to each experiment, for students to explain the underlying concept or principle : A. If the leaves used are not variegated what difference would it make in drawing inferences ? B. If whole leaf is kept inside the bottle in Moll's experiment what conclusion would be drawn ? C. CO_2 fixation has nothing to do with light phase. Give reason.	(a) Observe the given demonstrations and make their interpretations. (b) Identify the principle having bearing on the problem. (c) Recall the related facts and concepts. (d) Devise experiment under the guidance of teachers. (e) Control the variables in the experiments. (f) Draw conclusions based on the observations. (g) Pose questions for clarification. (h) Respond to teacher's questions.	Following types of questions may be asked : (i) Why do we use water plants in bubble experiment ? (ii) What will be the effect on the rate of oxygen evolved if the apparatus is shifted from the open space to a room ? (iii) What else would you suggest if KOH is not available in the laboratory for Moll's experiment ? (iv) Under what condition the rate of photosynthesis would not increase even with the increase in the intensity ?
3.3 Predicts the effect of various factors and raw materials on the rate and mechanism of photosynthesis.	D. Why heavy water and not ordinary water is used to determine the source of oxygen ? E. What will happen to rate of photosynthesis if CO_2 percentage in atmosphere falls down considerably ?		

(*a*)	(*b*)	(*c*)	(*d*)
4.0 ANALYSIS : The Pupil			
4.1 Identifies the product of photosynthesis from the remote past, recent past and present times. 4.2 Recognise assumptions underlying phenomena like evolution of O_2 from water testing of starch and not glucose as the end-product necessity of light, etc.	A. To what extent petroleum, coal and wood can be regarded as product of photosynthesis ? B. Is coal a product of photosynthesis ? C. What is the difference between coal and wood as product of photosynthesis ? D. Name two products of photosynthesis from remote past and recent past. E. We test for starch although take glucose as the end-product. What is the underlying assumption ? F. Potato tuber contain starch. Light is necessary for starch production as we say. Account for this contradiction.	(a) Pupils explain the plant life as basis of all. (b) Detect that wood, coal, petroleum, etc., are due to photosynthetic activity. (c) Explain the basis. (d) Name the products like petroleum and coal. (e) Glucose is a precursor of starch. (f) Try to relate starch formation in tuber as a stored product, converted from glucose produced in other leaves of aerial branches. (g) Try to analyse and judge the logic involved. (h) Identify the basis or the common elements by inter-relating the factors in the two or more setups.	(i) Wood and coal are due to photosynthesis. Explain. (ii) On what basis can we say that for starch production light is not necessary. (iii) Coleus leaves can produce starch in darkness. Under what conditions ? (iv) If light is necessary for starch production then how do you account for presence of starch in potato tuber ? (v) What is the difference in the interpretation of the conclusions which may be drawn from the three experiments, i.e., variegated leaf, tuber and petiole experiment ? (vi) Light is the cause of glucose which in turn is the cause of starch. Explain.

(a)	(b)	(c)	(d)
4.4 detects the principle underlying experimental procedures in variegated leaf experiment tuber and petiole experiment.	G. Provides situations with changed controls or variables for students to identify the common elements or the basis in the two or more apparently identical sets of experiments. H. Can we conclude from the above (F) that for starch production light is not necessary ?	(i) Understand the causal relationship as under : Light → Glucose ↙ Starch.	
5.0 SYNTHESIS : The Pupil			
5.1 Presents in a new tabulation form the photosynthetic activities of different leaf structures and the mechanism of photosynthesis in a symbolic form. 5.2 Proposes hypothesis to explain the process of photosynthesis.	A. Asks students to prepare a 3-dimentional table to express the inter-relationship of (a) Leaf structures (b) Adaptation of each structure (c) corresponding photosynthetic activity carried out.	(a) Identify the relationship among the three dimensions. (b) Prepare the table representing the 3-dimensions prescribed. (c) Different pupils process in different manner the mecha--nism of photosynthesis.	(i) Compare the different structure in leaf anatomy to that of different department in a factory indicating the correspondence of functions. (ii) Prepare a flow chart combining the different steps involved in the light phase and dark phase shown in the textbook on page 25.

	(a)	*(b)*	*(c)*	*(d)*
5.3	Suggests alternative methods and experimental procedures to test hypothesis related to photosynthesis.	B. Asks students to express the mechanism of photosynthesis in any form other than the textual form. C. Provides guidance when asked for to accomplish the given task. D. Asks pupils to propose a hypothesis to explain the exchange of gases during photosynthesis. E. Devise an experiment to demonstrate that light is not necessary for starch formation. Provides hint (if necessary) about using petioles of Coleus leaves in 5% sugar solution and water and test for starch.	(d) Ask for classification in respect of mode of representation of the process. (e) List the hypotheses about the role of stomata spongy tissue, etc. (f) Suggest experiment where sugar as a precursor to starch formation is already present as indicated in 2nd column(E).	(iii) When stomata remain open starch formation is there. But when they are closed no starch is formed. Propose a hypothesis to explain this. (iv) Chlorophyll is not necessary for photosynthesis. How will you test this hypothesis ? (v) Suggest any alternative experiment in place of typical Moll's experiment to show that CO_2 is essential for photosynthesis.

(a)	(b)	(c)	(d)
6.0 EVALUATION : The Pupil			
6.1 judges the adequacy and relevance of the given data or experimental procedure used to demonstrate or verify concepts related to photosynthesis. 6.2 makes appraisal of the validity, consistency and logic of the given conclusions and evidence about process of photosynthesis in terms of prescribed criteria.	A. A new problem like the following is posed and followed by means of sequential questions : A plant without green leaves cannot manufacture food. Does the hypothesis apply to all plants ? B. If this plant is able to manufacture food what must be assumed ? C. Can we say that such a plant can manufacture food if its stem is green and flattened ? D. What other contrivances or modifications should it develop to become a good autotroph ?	(a) Identify the consistent statement. (b) Reason out the answer in respond to questions by teacher. (c) Judge each statement or conclusion in terms of given criteria. (d) Find out whether the given conclusions are valid and logical. (e) Judge whether the given procedures are relevant to test the proposed hypothesis. (f) Raise 'evaluation' based question like : Oxygen comes from carbon dioxide during light phase instead of water, as it was thought earlier what is the basic fallacy in this statement in the light of our knowledge	(i) Which of the chemical reactions or steps have yet inconclusive evidence about photosynthetic process ? (ii) Photosynthesis takes place during light hours only. To what extent this statement is consistent with their current knowledge ? (iii) From the variegated leaf experiment which of the following conclusions can be drawn logically : (a) Chlorophyll is essential for starch formation. (b) Light is essential for photosynthesis. (c) Starch and not sugar is the end-product of photosynthesis.

(*a*)	(*b*)	(*c*)	(*d*)
	E. On what basis you can say that this hypothesis is acceptable ?	of mechanism of photosynthesis ?	(iv) After study of the prescribed text, write a question of your own the answer of which is not available in the text.
	F. Statements like the following are given for students to choose the inconsistent ones. (i) In Moll's experiment the half of the leaf is kept outside the bottle to act as control. (ii) Plant is kept in the dark to deprive leaf of chlorophyll. (iii) Sugar is first formed and then the starch.		

4. REVIEW QUESTIONS AND ASSIGNMENTS

Following types of questions were used :

(i) List four steps in order, involved in the process of photosynthesis during light phase.

(ii) Write a chemical equation representing the mechanism of photosynthesis using heavy water.

(iii) Give an example of homeostatis in relation to photosynthesis.

(iv) CO_2 acts as a limiting factor in the process of photosynthesis. What does this mean ?

(v) How will you demonstrate that sugar is a precursor to starch formation ?

(vi) When certain leaves are kept in dark for many days they were found to be without any soluble carbohydrates and became etiolated too. When these were put in sugar solution they became green again. Propose a hypothesis to explain this.

(vii) Why does a fish live longer in an aquarium if Elodea plants are introduced in it ?

(viii) Sow three bean seeds in different pots A, B and C having the same soil under the same conditions. After some days when seedlings come out then cut one leaf in 'A', both the leaves in 'B' and keep the 'C' as it is. After 4-5 days measure the length and diameter of each of the plants. Note the difference at regular intervals and draw your conclusions on the observations made by you.

(ix) Draw a schematic diagram of your own to depict the light and dark phases to explain the mechanism of photosynthesis more clearly to the weak students.

OBSERVATION SCHEDULE

ANNEXURE—C

	CRITERIA USED FOR IMPROVED TEACHING		EVIDENCE OF HAVING APPLIED THE CRITERIA	A (Good)		B (Satisfactory)		C (Poor)	
				Rater x	Rater y	Rater x	Rater y	Rater x	Rater y
1.0	Statement of expected learning outcomes (ELOs)	1.1	Announcement of expected learning outcomes at introductory stage of lesson to motivate the students	...	...	...	...	...	...
		1.2	Distributing the list of ELOs to students	...	...	...	...	...	...
2.0	Testing of prerequisite learning essential for the current lesson	2.1	Use of questions to test basic concepts relevant to the lesson	...	...	...	...	...	...
		2.2	Clarification/elaboration/reteaching of concepts basic to the lesson in hand	...	...	...	...	...	...
3.0	Relevance of method of teaching to intended learning outcomes.	3.1	Use of problem-solving approach	...	...	...	...	...	...
		3.2	Use of relevant media	...	...	...	...	...	...
		3.3	Formative evaluation	...	...	...	...	...	...
4.0	Index of students' involvement	4.1	Dominance of teacher in lower level ELOs	...	...	...	...	...	...
		4.2	Dominance of pupils in higher level ELOs	...	...	...	...	...	...
		4.3	Emphasis on independent learning	...	...	...	...	...	...
5.0	Use of questions as a teaching device	5.1	Use of different level questions catering to all the six types of ELOs	...	...	...	...	...	...
		5.2	Encouraging pupils to pose question at levels higher than memory	...	...	...	...	...	...
6.0	Use of thought provoking assignments	6.1	Giving assignments involving higher level objectives	...	...	...	...	...	...
		6.2	Requiring pupils to undertake group projects	...	...	...	...	...	...

6

6.0 DEVELOPMENT OF THE POST-TEST

To evaluate the gains of the students in support of the experimental hypothesis preparation of the post-test was a foregone requirement. But it was a formidable task. There is no gainsaying that in an experimental project like this all efforts would be futile if appropriate measuring instruments are not used to measure academic achievement of students. As pointed out in the theoretical frame of reference and as implied in the statement of hypotheses, the tool needed for measurement of student's abilities was of a different nature. It did not only demand a lot of time but also a good deal of patience, hard work and competence on the part of the test constructor. Besides, the tests available in the field were not of the type needed in this study. A test which might have been based on a specific content and which covered all the taxonomic objectives was not available. In fact, the present investigation demanded a test which should be based on different concepts each of which could be tested at various levels of the taxonomy of instructional objectives. It was an uphill task to prepare a test which could meet these requirements. It took more than four months to finalize the test which was used as a post-test.

6.1 CONSTRUCTION OF THE TEST

For construction of the post-test, the first draft covering 24 concepts from 10 units of teaching, comprised of 144 items. Since teaching was done in accordance with the school schedule, those very ten units were selected for framing of the post-test. However, one of these ten units was not prescribed for the class IX which followed the new syllabus under the 10+2+3 pattern of schooling. Even then, this was interpolated in the sequence of teaching units because this unit on diffusion and osmosis was basic to learning of other physiological processes which were to be taught. These were the units that were later on analysed for identification of major concepts which formed the basis for construction of items.

6.1.1 CONTENT ANALYSIS OF THE UNITS

It was no easy task to visualize a specific content amenable to testing at all the six levels of the taxonomy. It really proved so. At the beginning when construction of test items was undertaken it was not possible to frame items on any content. The same was true with respect to the different concepts on which items were being framed. In fact it was a very challenging experience to develop items ranging from knowledge to evaluation, testing the same concept. One had to come back to the position of 'nothing in stock' after framing three or four items with two still remaining, on the same concept. It was, therefore, after a good deal of trial and error that necessity was felt of identifying only those concepts that had good potential of being used for construction of items at all the six levels of the taxonomy of educational objectives.

There followed the screening and content analysis of the units already selected for teaching vis-à-vis testing. Ultimately it came to only those major concepts which were more potent than others, that the final list of concepts was made. It was not difficult to decide that number of concepts needed finally for the post-test, should be at least double the number desired in the final form of the test to meet an eventuality that might arise during try out. To be still on the safer side it was possible to identify the 24 major concepts which formed the basis of framing the first draft of test items. The following table indicates the selection of these concepts from among the various topics prescribed in the syllabus. It did contain some of the topics which had no place in the final format of the test, the reasons for which are given under the head 'finalization of the test'.

6.1.2 FRAMING OF TAXONOMIC ITEMS OF THE FIRST DRAFT

As discussed in the introductory chapter there can be different modes of validation of the taxonomy. The usual method used in most of the earlier studies is the product oriented approach to validation. In this approach product of performance is taken as the base data while the process of performance is relegated to the background. For this any random selection of items can be used to measure students' achievement. Such an approach ignores the role of the content in developing the abilities. Since content is the medium through which the attainment of the instructional objectives is sought to be tested, it is essential that any difference that may be observed in the achievement of the students, should not be simply due to the difference in their previous learning or unfamiliarity with the content.

There could be three different ways as Kropp, Stoker and Bashaw (1966) point out in dealing with this type of situation. One, we may assume that teaching variable is the same for all the students in particular class. As such they have the necessary knowledge and background as a part of their instructional antecedents. In such a case stray items from any test pool could be used for validation purposes. But it is difficult to believe this assumption keeping in view that the teaching facilities and the competence of teachers vary so much from school to school. Therefore this method was not considered appropriate.

Equalization of content as a base material was, therefore, considered essential to test the develop abilities ranging from simple 'recall' to the most complex, 'evaluation'. This is made possible by giving a paragraph relating to the contributing of the life giving a comprehension paragraph in English text, followed by a number of questions on that paragraph. This could not be adopted for two reasons ; namely, the difficulty of writing a paragraph which could provide enough potential to frame all the six questions testing the fundamental concept on which the particular paragraph was developed. Secondly, it was difficult to safeguard against framing of

Table 5

UNIT-WISE CONCEPTS SELECTED FOR THE FIRST DRAFT

Sl. No.	Concepts selected	Unit of teaching
**1	Conditions for seed germination	Living things
***2	Geotropism in plants	Living things
*3	Animal tissues	Plant and animal tissues
*4	Plant tissues	Plant and animal tissues
*5	Modification of roots	Organ, organ system and organisms
**6	Root and absorption	Organ, organ system and organisms
***7	Different levels of organisation	Levels of organisation
°8	Diffusion of molecules through living membranes	Diffusion and osmosis
**9	Osmoregulation by contractile vacuole	Diffusion and osmosis
°10	Enzymes and their functions	Nutrition
*11	Vitamins and prevention of diseases	Nutrition
°12	Chloroplast as a site of photosynthesis	Photosynthesis
**13	Light and opening of stomata	Photosynthesis
**14	Light and splitting of water	Photosynthesis
°15	Carbon dioxide in photosynthesis	Photosynthesis
°16	Chlorophyll in photosynthesis	Photosynthesis
*17	Limiting factors in photosynthesis	Photosynthesis
°18	Anaerobic respiration	Respiration
**19	Mitochondria as a site of respiration	Respiration
°20	Different systems of internal transport in animals	Internal transport
°21	Xylem and Phloem in transport	Internal transport
°22	Stomata and regulation of transpiration	Internal transport
°23	Plasmolysis	Diffusion and osmosis
*24	Forest and balance in nature	Conservation of natural resources

* Rejected on the basis of opinion of experts.
** Rejected after tryout.
*** Rejected to ensure homogeneity of content.

simple knowledge questions that might be immediately answered just by reading the text.

The third method which was considered appropriate for use in this study was the use of predetermined concept as the basic content on which all the six items could be constructed. Such an approach could be practicable in testing the experimental as well as the theoretical hypotheses with the same material. The additional advantage of developing this type of material was the complete elimination of the possibility for a student to attempt correctly or incorrectly an item simply because he is not familiar with a particular content.

Kropp and his Associates (1964) while discussing the various issues involved in the validation of the taxonomy have discussed the role of the formation of the items also. Though validity of the students' responses to the open ended questions is likely to be more as compared to the responses on the selection-type items, yet because of the difficulty of scoring and subjectivity involved, it has profound influence on the reliability of the items. Since construct validity could be taken care of in the construction of the items based on the various objectives followed by other procedures like that of raters' validity and discriminant validity it was considered more appropriate to make use of only multiple choice items in the test envisaged for the purpose. This was also necessitated by other limiting factors like time, ease of scoring and interpretation and handling of the data. Thus multiple choice items with four alternatives were the final format of the items used in the test.

In order to keep the same content as the base material for construction of the items at various levels of the taxonomy it was essential that major concepts from each topic may be taken as a medium for testing pupils' achievement at different levels. Thus each concept selected was central to the framing of items testing all the six objectives. Six items based on a single concept were framed to measure students' achievement at different levels ranging from simple Knowledge items to the most complex items on Evaluation. So no item had its independent identity but was a part of the complete set of six items. In a way this also made it clear to compare one item with the other in the set with reference to the objective it was supposed to measure. It was not unusual to shift places of these items especially at the higher level as it provided a good exercise for improving inter-item logical validity.

As reported earlier, to begin with 24 concepts in all were selected. On each of these concepts a set of six items was constructed, thereby making a total of 144 items in the first draft of the item constructed for the test. In this an attempt was made to cover almost all the subcategories of the objectives. This however could not be maintained in the subsequent versions of the test. For making the items relevant to each of the subcategories implied in the six objectives, the examples given in the Bloom's taxonomy were consulted. Other major sources used were the B.S.C.S. Test Booklet for high school biology (1966), Testing and Evaluation in Sciences by Hedges (1966) and C.U.E.B.S. Report (1967).

The investigator was fortunate to get the expert advice of his colleagues in the Examination Reform and Research Units of the National Council of Educational Research and Training by having occasional shredding sessions to discuss the items set by set. Apart from improving the quality of the items from the point of view of their mechanics, main purpose was to see the relevance of each item to the corresponding category of objective it was supposed to measure. Critical examination of the first draft, item by item, improved the quality of the test in general.

6.1.3 TEST FORMAT

The 144 items to be presented to the raters, as indicated earlier, covered 24 concepts with 6 items on each concept designed to test the six objectives of the taxonomy. Each set of the six items was arranged in a random order by drawing lots and was put on one page to avoid giving any clues to the raters on the basis of the placement of items. Thus items on each concept were kept together at one place. For this 6 items of each set were placed in random order under the one common heading, i.e., the complete statement of the concept on which items were developed. Thus on each page of 24-page document, there was the statement of a biological concept followed by random placement of six items based on the concept.

Six randomised sets were prepared by lot and were used in cyclic order one after the other in case of the twenty-four sets of items. Statement of the concept on the top was considered useful for focussing attention of the raters on the concept which the researcher was interested to test. Moreover, it did provide some clue to the raters to see if the items constructed were of the level which could be expected if students are taught at that level.

6.1.4 USE OF REFERENCE NOTE

From the above list it was quite obvious that the persons entrusted with the task of classification were quite competent having background in evaluation. On the basis of investigator's own experience of classifying the same item in different classes when classified at different times, it was useful to fall back upon illustrative examples. Referring back to the example given in the Bloom's text ultimately helped to decide the place of an item in a particular category. Therefore some sort of guidelines for the evaluators was considered essential to enable them to fall back upon some resource material which could improve judgmental validity of the raters in allocating the different items to their respective categories. For this a reference note was prepared for use of the raters.

Along with the forwarding letter to the raters requesting them to classify the items a reference note for guidance of those who may like to use it was also sent. This note, a copy of which is given in Appendix-A consisted of a brief preamble, followed by the listing of each objective of the taxonomy. Each objective was further explained in details using the original terminology and description under the heads : Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. This description was followed by illustrative questions, one on each of the subcategories of the taxonomy. In all 21 examples, representative of each of the specifications, were included in the reference note. These items were of the multiple choice type. These items were mostly called out of the original items given in the Handbook on Taxonomy of Educational Objectives. In a few cases, however, it was not possible to do so because biology items were not available. In such cases, items were taken from other standard works like the collection of items in the C.U.E.B.S. Report (1966) and the text by Hedges (1966) referred to earlier.

6.1.5 CLASSIFICATION OF ITEMS BY RATERS

After the first level vetting with the help of subject experts in evaluation the material consisting of 144 items was cyclostyled for despatch to the raters for their classification into six categories. Since the whole material consisting of 24 pages with 144 items of the multiple choice variety formed an unusually heavy load it was not an easy task for the evaluators to go through and classify each item according to the taxonomical scheme.

This task seemed to be unsurmountable. Besides the magnitude of labour involved in this imposed task, the evaluators were to be well conversant not only with the Bloom's taxonomy of educational objectives but also the knowledge of the biological sciences. This was a problem as it was difficult to find persons who possessed expertise both in the taxonomy and the content of Biology. Many experts of taxonomy were not familiar with the content and many of biology experts had little understanding of the taxonomy.

As the investigator had been engaged in the training of resource persons in evaluation all over India for more than one decade the task became a little easier to identify the raters for classification of the items. Keeping in view the number of suitable persons available for this task and the ardous nature of the time consuming task it was decided to prepare a list of about 40 to 50 evaluators who were later on requested to oblige the researcher by doing this job for him. The persons belonged to the colleges, schools, universities, boards of secondary education, state institutes of science education and the National Council of Educational Research and Training. In all 45 letters were issued out of which 22 responded who completed the task of categorisation. Those who did this job were persons, with rich, long experience in this type of task. Item-wise agreement of 22 raters is given in Table 6.

6.1.6 CRITERIA FOR ACCEPTANCE OF ITEMS

A lot of variation in the reallocation of the items as compared to the allocation made by the author is evident. However, there was no doubt about many of the items which could be selected without any further consideration. Similarly it was possible to reject outright some of the items which showed unexpectedly large variation. In spite of that, it was difficult to decide the rejection or acceptance of an item on this criterion alone.

Since complete sets of six items each, were to be accepted or rejected, all such sets of items were accepted in which

(i) the agreement ratio of all the items constituting a set was 50% or above ;

(ii) only one item had a ratio of less than 50% while the remaining ones had higher agreement ratios. Wherever possible the item with less than 50% ratio was modified to make it more relevant ;

(iii) items were considered essential from the point of view of the coverage of content. If they had one or two defective items, they were either modified or accepted as they were. Some of the defective items had obvious deficiencies and a slight modification in the choices could make them more pointed.

On the basis of the above-mentioned criteria, six sets of items, i.e., 36 items based on concept Nos. 3, 4, 5, 11, 17 and 24 were rejected from the first draft of 144 items comparing the 24 concepts. The 108 items based on the remaining 18 concepts, were then re-edited to make necessary improvements. This was specially necessary in case of items which showed more divergence of the opinion of the raters.

Table 6

ITEM-WISE AGREEMENT OF 22 RATERS ON 144 ITEMS

Total Number of Judges=22						*Rejected after raters reclassification					
Item No.	Concept	Number Agreed	Item No.	Concept	Number Agreed	Item No.	Concept	Number Agreed	Item No.	Concept	Number Agreed
1	*I*	9	37	*VII*	3	73	*XIII*	15	109	*XIX*	6
2		7	38		19	74		6	110		7
3		10	39		13	75		17	111		15
4		12	40		11	76		15	112		10
5		20	41		11	77		15	113		10
6		11	42		16	78		15	114		10
7	*II*	7	43	*VIII*	16	79	*XIV*	16	115	*XX*	13
8		11	44		13	80		14	116		13
9		11	45		10	81		18	117		17
10		11	46		11	82		19	118		15
11		10	47		12	83		16	119		10
12		19	48		14	84		17	120		17
13	**III*	20	49	*IX*	9	85	*XV*	14	121	*XXI*	20
14		4	50		10	86		15	122		14
15		5	51		17	87		15	123		19
16		7	52		10	88		11	124		15
17		8	53		10	89		6	125		18
18		5	54		9	90		18	126		10
19	**IV*	5	55	*X*	14	91	*XVI*	17	127	*XXII*	13
20		10	56		20	92		14	128		21
21		21	57		14	93		19	129		16
22		5	58		11	94		9	130		17
23		18	59		9	95		2	131		12
24		15	60		6	96		5	132		21
25	**V*	9	61	**XI*	4	97	**XVII*	7	133	**XXIII*	14
26		16	62		5	98		5	134		11
27		10	63		5	99		7	135		12
28		6	64		6	100		7	136		6
29		6	65		8	101		5	137		7
30		10	66		8	102		14	138		10
31	*VI*	11	67	*XII*	8	103	*XVIII*	13	139	**XXIV*	9
32		10	68		11	104		7	140		4
33		9	69		10	105		7	141		15
34		14	70		11	106		11	142		7
35		15	71		5	107		10	143		2
36		7	72		15	108		9	144		3

6.1.7 REFINEMENT AND RECLASSIFICATION OF ITEMS

The investigator had the opportunity of conducting an All India workshop on unit testing in Biological Sciences organised at the Institute of Science Education, Udaipur, Rajasthan (India), in which very experienced teachers from schools, colleges, universities and state educational agencies participated. Advantage was taken of their presence in getting the test material again vetted. With the help of the reference note already prepared and used by the raters, these 20 experts in biology with good experience of participation in evaluation workshops were oriented in the Scheme of Bloom's classification of objectives. With the help of those items which were rejected earlier, practice was given in categorisation of items. This was followed by grouping of participants into four subgroups of five experts each. They were asked to classify the items after discussing each item and to modify as and when necessary to fit into the pre-determined objectives which each item was supposed to test.

This procedure of validating the items not only improved further the quality of the items but also made it easier to classify the items more accurately into the six tiers of objectives. Since only 24-30 items were given to each subgroup (total being 108), experts got sufficient time to discuss and thrash out items for their improvement before allocating them into their respective categories. In fact, this process provided for opinions of five judges on each of the items although the panel of judges varied with each set of 24 to 30 items. At the end it was encouraging to note that there was no less than 80% of agreement among the raters for classifying those items. This was considered quite satisfactory for the purpose of test.

6.1.8 TRYOUT OF THE SECOND DRAFT OF ITEMS

The items so finalised were sequenced concept-wise in order of increasing complexity of objectives and typed for administration to five students on a pilot basis. Students were simply asked to attempt the items which they thought were confusing or which admitted of more than one answer. Most of the students were able to complete the test in about 90 minutes. The test was given in two parts at two different sittings on two consecutive days. Students came from a local central school having English as the medium of instruction. But for minor editorial corrections in the format and content of items, no substantial change was made in the test which was now ready for tryout on a bigger sample. As a result of pilot tryout testing time was estimated for the second draft.

It is a well-known principle that the tryout sample should be drawn from the population on which the test is to be used. In the present study the population was to be the students of classes IX to XI of the boys, girls and coeducational schools. Therefore, it was appropriate to select a coeducational school which could represent both the sexes in this tryout. Cox's study (1965) clearly indicated that the sex make up of the tryout group makes a difference in selection of certain type of items for inclusion in the final test term. Central School Sector IV, R. K. Puram was, therefore, the choice for this tryout.

Another decision to be taken was about the class for administration ,because in the final administration the test was to be given to all the three classes IX, X and XI, to test one of the theoretical hypotheses, namely, that cognitive behaviours designated in the taxonomy were learnt behaviour. Although the content of the test was the same for all the three classes yet the standard of these classes could be different. Therefore the median class, i.e., class X was the obvious choice so that the test was neither pitched too high nor too low.

The test being long, 108 items were divided into two parts, consisting of 60 and 48 items respectively to be administered at two different sessions. One hour was given for each administration. Approximately 90 minutes for both parts provided to be quite sufficient for almost all the students to complete the test. This was despite the instructions given to the students to have more time, if they needed. Other usual instructions to motivate them and enlist their cooperation were given for the guidance of the examinees. The test was administered finally to 100 students of class X.

6.1.8.1 ITEM ANALYSIS OF 108 ITEMS

There is no disagreement among experts that for a test to be valid, there must be a high degree of correspondence between instructional objectives and the test items. Evaluation of items, therefore, involves both thoughtful and subjective evaluation by subject matter experts as well as the statistical measures comprising of item difficulty and discrimination Cox (1965) remarked :

> "If we rely solely on statistical data in the selection of items, certain biases are introduced into the final test. Moreover, a type of behaviour measured with the test item (Taxonomy classification) interacts with difficulty and discrimination values. Statistical items selection alone is not sufficient. Therefore a selection of item from an item pool on the basis of discrimination analysis may be biased in favour of the group of items which contain the highest average discrimination value. This suggests the possibility of selecting the most discriminating item within a particular taxonomical category rather than selecting the most discriminating items from the total item pool."

In the present test, therefore, apart from the discrimination index other considerations were also kept in view while accepting or rejecting a particular item. One major deciding factor as stated earlier was that acceptance or rejection was made not of individual items but of a complete set of six items testing objectives at six taxonomic levels. Thus an item was selected even with its low discrimination index when the other 4 or 5 items in that set had reasonable indices of discrimination. Likewise, one or two items even with low discrimination indices were selected, when re-examination of such items revealed some glaring omission or commission of some in the form of clue or doubtful key. Discrimination indices are given in Table 7.

Table 7

DISCRIMINATION INDICES OF ITEMS OF 2ND DRAFT

No. of items : 108

Item No.		Dis. Index	Avg. Disc. Value	Item No.		Dis. Index	Avg. Disc. Value	Item No.		Dis. Index	Avg. Disc. Value	Item No.		Dis. Index	Avg. Disc. Value
	Concept				Concept				Concept				Concept		
1	*I	0.63		31	*VI	0.25		61	*XI	0.11		91	XVI	0.37	
2		0.63		32		0.11		62		0.22		92		0.48	
3		0.07	(0.34)	33		−0.03	(0.25)	63		0.44	(0.24)	93		0.70	
4		−0.15		34		0.25		64		−0.03		94		0.33	
5		0.51		35		0.51		65		0.63		95		0.48	
6		0.22		36		0.37		66		−0.07		96		0.33	
7	II	0.29		37	VII	0.55		67	XII	0.11		97	XVII	0.48	
8		0.33		38		0.51		68		0.66		98		0.55	
9		0.77	(0.44)	39		0.51	(0.44)	69		0.85	(0.50)	99		0.22	
10		0.25		40		0.15		70		0.48		100		0.70	
11		0.30		41		0.63		71		0.51		101		0.44	
12		0.70		42		0.29		72		0.33		102		0.66	
13	III	0.55		43	VIII	0.55		73	XIII	0.55		103	XVIII	0.48	
14		0.59		44		0.37		74		0.44		104		0.70	
15		0.51	(0.44)	45		0.41	(0.36)	75		0.41	(0.50)	105		0.44	
16		0.59		46		0.37		76		0.55		106		0.37	
17		0.15		47		0.18		77		0.33		107		0.70	
18		0.29		48		0.25		78		0.74		108		0.55	
19	*IV	0.07		49	IX	0.22		79		0.66					
20		−0.00		50		0.41		80		0.37					
21		0.15		51		0.41		81		0.41					
22		0.29	(0.16)	52		0.33	(0.38)	82		0.37	(0.42)				
23		0.18		53		0.70		83		0.41					
24		0.29		54		0.22		84		0.29					
25	V	0.59		55	*X	−0.07		85	*XV	0.15					
26		0.22		56		0.48		86		0.59					
27		0.29		57		0.11		87		0.22					
28		0.55	(0.44)	58		−0.00	(0.12)	88		0.00	(0.38)				
29		0.51		59		0.00		89		0.81					
30		0.48		60		0.18		90		0.48					

*The sets of items rejected on the basis of discrimination indices

Table 8

DIFFICULTY INDICES OF ITEMS OF 2ND DRAFT

Tryout Form
No. of Items : 108

Item No.	Concept	Diff. Index	Avg. Diff. Index	Item No.	Concept	Diff. Index	Avg. Diff. Index	Item No.	Concept	Diff. Index	Avg. Diff. Index	Item No.	Concept	Diff. Index	Avg. Diff. Index
1	*I	0.71		31	*VI	0.67		61	*XI	0.01		91	XVI	0.87	
2		0.52		32		0.78		62		0.28		92		0.69	
3		−0.13		33		0.46		63		0.03		93		0.38	
4		0.27	(0.27)	34		0.51	(0.60)	64		0.05	(0.13)	94		0.71	(0.55)
5		0.29		35		0.70		65		0.31		95		0.50	
6		0.03		36		0.45		66		0.07		96		0.13	
7	II	0.28		37	VII	0.55		67	XII	0.12		97	XVII	0.70	
8		0.76		38		0.48		68		0.35		98		0.56	
9		0.60	(0.61)	39		0.28	(0.45)	69		0.39	(0.31)	99		0.53	(0.44)
10		0.08		40		0.42		70		0.37		100		0.24	
11		0.26		41		0.67		71		0.42		101		0.36	
12		0.43		42		0.32		72		0.21		102		0.25	
13	III	0.65		43	VIII	0.59		73	XIII	0.80		103	XVIII	0.29	
14		0.46		44		0.12		74		0.69		104		0.23	
15		0.54		45		0.22		75		0.56		105		0.44	
16		0.26	(0.50)	46		0.41	(0.29)	76		0.14	(0.51)	106		0.55	(0.50)
17		0.36		47		0.13		77		0.35		107		0.66	
18		0.71		48		0.25		78		0.50		108		0.80	
19	*IV	0.83		49	IX	0.87		79	XIV	0.37					
20		0.23		50		0.84		80		0.61					
21		0.22	(0.18)	51		0.87	(0.70)	81		0.72	(0.41)				
22		0.18		52		0.76		82		0.23					
23		0.02		53		0.71		83		0.34					
24		0.05		54		0.14		84		0.19					
25	V	0.60		55	*X	0.04		85	*XV	0.84					
26		0.16		56		0.24		86		0.71					
27		0.09	(0.33)	57		0.89	(0.23)	87		0.51	(0.51)				
28		0.40		58		0.15		88		0.25					
29		0.34		59		0.11		89		0.65					
30		0.37		60		0.16		90		0.12					

On the basis of overall average discrimination index, the set of items relating to concepts 1, 6, 9, 13, 14 and 19 (Table 5) or 1, 4, 6, 10, 11 and 15 (Table 7) were excluded for the final test. On further analysis two more concepts Nos. 1 and 15 were discarded because of either 0.00 or negative discrimination indices of one or two items in the set of six. Discrimination index of 0.20 was considered as minimum for retaining a particular item. Thus, 72 items in all based on 12 concepts were left. It were these items whose difficulty levels were further verified. The difficulty indices as seen in Table 8 varied from 0.11 to 0.89. From the point of view of difficulty indices, there were only four items having difficulty level above 85% and 19 items with difficulty level below 15%.

Since 36 items on six concepts were already rejected for want of high discrimination, there were only 72 items left for judging them in terms of difficulty indices. Out of these 72, there were only 2 items which were beyond 85% difficulty level but there were 10 items which had difficulty level below 15% ranging between 8 to 14. These were retained as such. It may be mentioned here that these difficulty indices were calculated after having used the correction formula on the raw scores. Although discrimination and difficulty values of the 108 items were the basis of choice of items for the final test it was considered desirable to ascertain the reliability of the test (2nd draft). For this the simple formula which approximates Kudar Richardson's formula, devised by Saupe (1961) was used. The formula is :

$$r_{tt}=1-\frac{0.19\,K}{(SD)^2}$$

where r_{tt} = The reliability coefficient

$(SD)^2$ = Standard deviation of the observed scores

K = The number of items on the test

0.19 = A constant.

Reliability coefficient was 0.84 which was quite satisfactory.

6.1.9 FINAL TEST FORMAT OF 60 ITEMS

After trying out of 108 items (Second draft) only 72 items testing 12 concepts were left for the final test. Out of these, 60 items were from the area of physiology covering five major units. The remaining two sets of 12 items covering concepts 2 and 3 were from the other areas. In spite of the fact that these 12 items stood the test of discrimination and difficulty level, it was decided to drop them also in the final test for two reasons. Firstly, to reduce the number of items to 60 so as to make it possible to have a one hour testing time beyond which it becomes tiresome for students. Secondly, to make the test more homogeneous by eliminating the 12 items which were based on the units of 'Living things' and 'Organisational Levels' and not on physiology.

The final test of 60 items was, therefore, based on the portion of physiology. Unit-wise distribution of items along with the number of concepts are given in the Table 9.

Table 9

UNIT-WISE DISTRIBUTION OF ITEMS IN FINAL TEST

Sl. No.	Units	No. of Concepts tested	No. of Items included
1.	Osmosis	2	12
2.	Nutrition	1	6
3.	Photosynthesis	3	18
4.	Respiration	1	6
5.	Internal transport	3	18
	Total	10	60

The 60 items included in the Test Booklet were set in such a manner that on each page there are 6 items arranged in order of increasing complexity of the objectives, i.e., ranging from Knowledge to Evaluation. This was considered necessary for three reasons. Firstly, to discourage the students to read questions on the page that follows ; secondly, to enable the students to concentrate only on the 6 itmes at a time which are based on the same concept and thirdly, to enable the students to proceed from the simplest to the most complex item so that his mental processes are exercised in order of their complexity.

Besides the 10 sheets containing the item, the Test Booklet had one additional sheet. The title page of the booklet consisted of (i) identification data about the pupil and (ii) some general instructions. On the reverse side of the title page of the booklet there were specific instructions along with two solved examples and two examples for practice. The copy of the Test Booklet is given in Appendix-B.

Separate answer sheet was prepared as shown in Appendix-C. Items were arranged in this sheet objective-wise relating to each concept for convenience of scoring and totalling to get objective-wise and concept-wise scores. The key to 60 items is indicated in the answer sheet itself (Appendix-C) by putting a cross (×) in each box.

The test was thus ready for administration. The final test structure is given in figure 3 and the Taxonomic Biology Achievement Test is given in Appendix-B.

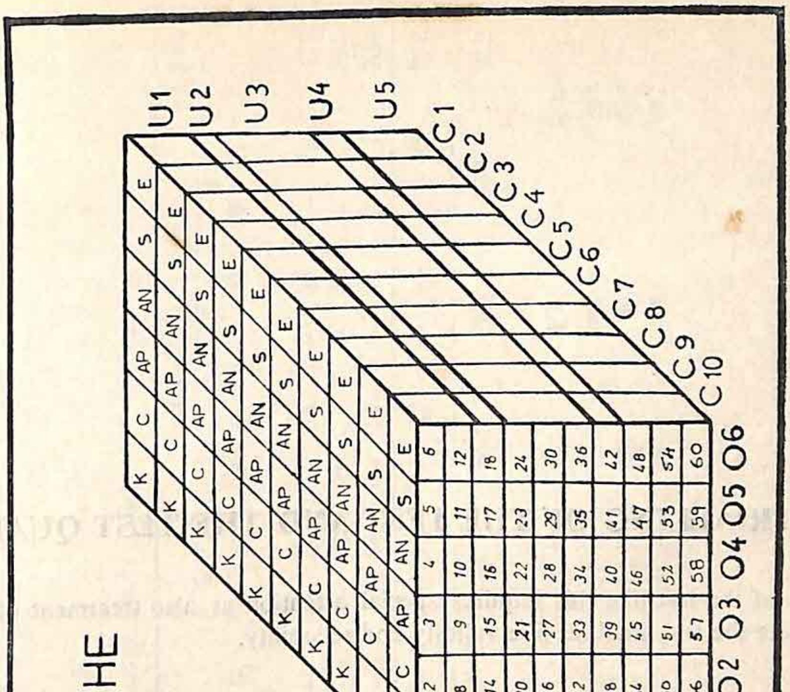

STRUCTURE OF THE FINAL TEST
U1
U2
U3
U4
U5
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
K
C
AP
AN
S
E
1 2 3 4 5 6
7 8 9 10 11 12
13 14 15 16 17 18
19 20 21 22 23 24
25 26 27 28 29 30
31 32 33 34 35 36
37 38 39 40 41 42
43 44 45 46 47 48
49 50 51 52 53 54
55 56 57 58 59 60
O1 O2 O3 O4 O5 O6
O Objective
c Concept
U Unit

Fig. 3

7

7.0 TRIALLING OF THE TEST AND THE TEST QUALITIES

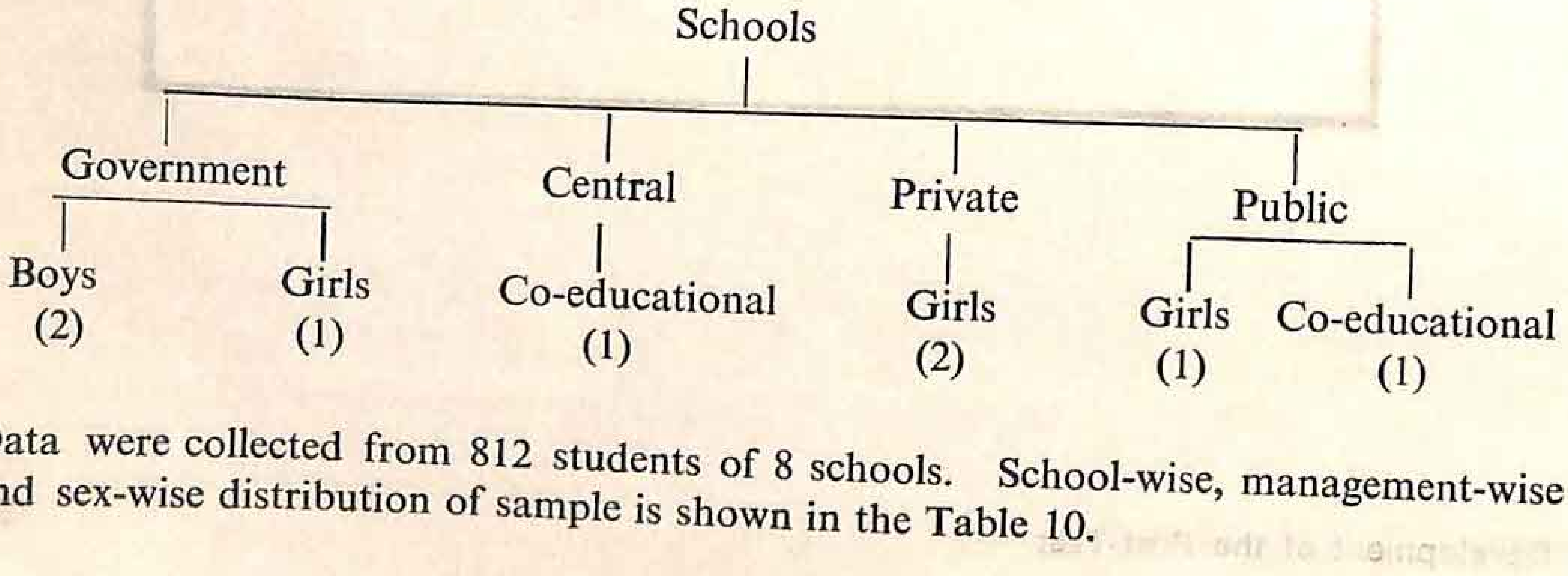
Try out of the test like this requires special attention as also treatment of the data to estimate the test qualities like validity and reliability.

7.1 ADMINISTRATION AND SCORING

For collecting valid and reliable evidence, proper sampling, readiness of testees, efficiency in the administration of the test, objectivity in scoring and proper recording of students' responses are the predisposing factors of which we have to be cognizant before administration and scoring of test. Decisions about these aspects are to be taken in advance and necessary conditions ensured.

7.2 SAMPLE FOR THE STUDY

Successful conduct of a project depends on the sample we use in collecting the data. It may be mentioned that selection of sample was not random. However, care was taken to select schools which represented the population of Delhi schools. Keeping in view the variable of sex, management and the medium of instruction the following schools were selected using stratified and quota sampling technique :



Data were collected from 812 students of 8 schools. School-wise, management-wise and sex-wise distribution of sample is shown in the Table 10.

Table 10

SEX-WISE DISTRIBUTION OF SAMPLE OVER THE CLASSES IN 8 SCHOOLS

Schools	Co-educational				Boys				Girls								Total
	1		2		3		4		5		6		7		8		
Sex	B	G	B	G	B	G	B	G	B	G	B	G	B	G	B	G	
Class																	
IX	50	26	25	07	34	—	42	—	—	29	—	36	—	43	—	29	321
X	49	24	19	09	36	—	27	—	—	30	—	33	—	42	—	22	291
XI	09	09	25	01	41	—	26	—	—	48	—	18	—	08	—	15	200
Sex-wise Total	108	59	69	17	111	—	95	—	—	107	—	87	—	93	—	66	812
School-wise Total	167		086		111		095		107		087		093		066		812

1-8 Schools
B—Boys
G—Girls

Classes	IX	X	XI	Total
No. of boys	151	131	101	383
No. of girls	170	160	99	429
Total	321	291	200	812

The first step in selecting the sample was to identify the universe. Since the investigator was employed in Delhi it was convenient to take up the higher secondary schools of Delhi as the population out of which sample could be drawn. The criteria for selection of schools was more than one. One, major criterion was the medium of instruction. Since the researcher himself was not competent to teach in Hindi and it was difficult to prepare objective-based material in Hindi it was considered essential that only those schools where medium of instruction is English may be selected. Secondly, sex was one variable on the basis of which it was decided to have schools of all the three varieties namely ; the boys, the girls and co-educational institutions. Another criterion was the reputation of the institution so as to include in the sample all types of schools having unsatisfactory, satisfactory and good reputation. The fourth criterion was to see that schools under various managements are represented. That is why it was decided to have Public schools, Government schools, Central schools and Denominational schools. Keeping these criteria in view, 8 schools in all were selected. Fifth criterion of rural urban consideration could not be used as there was not-even one rural school where teaching of biology through the medium of English was in practice. So no rural school could be included in the sample. Since the emphasis in the study was to integrate both teaching and testing for which regular teaching was also to be followed, it was not possible to select the sample on a more scientific basis. Keeping in view the facilities available and the cooperation extended to the investigator by the various schools, the list of schools was drawn. Since in this study, there was no attempt to make any prediction, the convenience, practicability and cooperation of the biology teachers were the main considerations for drawing the sample.

7.2.1 SAMPLE—A

Three types of samples were drawn. Sample-A consisted of 812 students from 8 different schools representing classes IX, X and XI (Table 10). This was the sample on which the product-oriented approach of validation was used. This sample consisted of 383 boys and 429 girls. Class-wise there were 321, 291, and 200 students representing the three classes IX, X and XI, respectively. This sample constituted the main sample on which the first three hypotheses listed under Chapter IV were tested (p. 38).

7.2.2 SAMPLE—B

The second sample which is called the Sample-B consisted of both Section-A and Section-B of class IX of one of the local Central schools. It were these two sections of class IX which represented the experimental and the control groups. It was against this sample that hypothesis No. 4 (p. 38) regarding the impact of objective-based instruction on development of students' cognitive abilities was tested. This sample consisted of 83 students of a co-educational institution. Both sexes were represented in this sample. The discrepancy observed in size of the Sample-B in Chapter VII is due to absence of some students either in the vocabulary (V) or numerical ability (N) tests or the post-test, at the time of administration.

7.2.3 SAMPLE—C

Sample-C was a part of the Sample-B representing Section-A only of class IX which was used as experimental group in testing the hypothesis No. 4. This Sample-C consisted of only 41 students (36 at the time of administration) forming the part of Sample-B. It was this Sample-C which received objective-based instruction and was used to test hypothesis No. 5 relating to identification of mental processes and finding the correspondence between the product-responses and process-responses.

These data were used for understanding student-generated hierarchy. This involved a special technique of administration and the researcher had no knowledge of this type of administration having been done earlier by any investigator. It was from the paper of Kropp, Stoker and Bashaw (1966) that some clues were available and were made use of in this study.

7.3 SOME ISSUES FOR ADMINISTRATION

The following were some of the issues which had to be sorted out to administer the test :

(i) Total time for which testees could be detained to undergo the ordeal of administration of 60 items.
(ii) Number and arrangement of items that could be administered at a time.
(iii) How to ascertain the mental process they used in attempting the items ?
(iv) How best to record the process responses and analyse them ?

7.3.1 TOTAL TIME AVAILABLE FOR ADMINISTRATION

It was discussed with the Principal, the biology teacher and the students. Two hours was the maximum time (i.e., about two minutes for a question) that could be spared by the school and students could be made to sit for the test. On actual administration it took a little less than two hours.

7.3.2 NUMBER OF QUESTIONS TO BE ADMINISTERED IN ONE LOT

In view of the nature of the task it was out of question to administer the whole test first and then require the students to verbalise their responses. The other possibility was to administer one item at a time by having a card for each item. This was not adopted because it would have deprived the students of the facility of comparing items among themselves in each set thereby making an already difficult task still more difficult. The third alternative was to administer one set at a time comprising 6 items ranging from Knowledge to Evaluation. This was finally done for three reasons. One, the testing time requirement would be met. It would be neither too long nor too short. Second, students would concentrate at a time on a single concept and would be in a better position to verbalise their responses while undergoing the rigour of using various mental processes in attempting a question. Third, the continued concentration on the same concept together with increasing complexity of the questions with which they are encountered, were considered most appropriate in this process of administration. That is why items were clubbed together in sets of six each based on the same concept, arranged in increasing order of their complexity rather than in random order.

The obvious danger in giving each test with the same arrangement of items from Knowledge to Evaluation was that the students may identify this pattern and respond accordingly. This was safeguarded against by telling the students that they need not try to identify the mental process on the basis of the position of the item in the set. They should rather concentrate on individual items and identify the relevant mental process. Moveover, the key statements which they were to use identifying the relevant mental process were arranged in a random order and not in the sequence of Knowledge to Evaluation.

7.3.3 IDENTIFICATION OF MENTAL PROCESS (PROCESS-RESPONSES)

To ascertain the mental process two approaches were visualised.

(a) That items be given as such and the students be asked to attempt an item, write the key in the answer sheet and immediately introspect and write on a given separate sheet the processes they used in attempting the item.

(b) That students be provided with a check-list comprising the expected mental process corresponding to each of the six objectives arranged in a random order marked *a* to *f*. The students may then be asked to identify the relevant process and enter the corresponding letter against the question number in a separate answer sheet.

Since the first approach could have yielded a more valid measure of students' verbalisations, this was first tried out using one set of six items, in one of the schools (not from the sample) for 18 students of class XI. The result was very discouraging. It was not possible for students to verbalise beyond two levels, Knowledge and Comprehension. Hardly any student could verbalise Application objective and beyond. It was, therefore, decided to resort to the check-list approach.

To provide students with a list of statements corresponding to the mental processes implied by each objective of the taxonomy was no less an arduous task. A comprehensive list of statements under each objective using the taxonomical vocabulary (to keep the original spirit) was prepared but it did not work well because a teacher and one of his own colleagues found it very cumbersome. Need was felt of a much shorter, precise and understandable list with as far as possible non-technical terms. For each objective one statement was prepared besides the one additional, i.e., 7th at the end, 'for any other process' that they might have used. After modifying five to six times, a list of six statements was ultimately prepared using directly or indirectly the key words of each objectives and the seventh statement was added for 'any other process used'.

Before finalising the check-list, it was tried out on a sample of 42 students at the State Institute of Science Education, Udaipur where the researcher had gone to conduct a seminar. Advantage was taken of the presence of 42 students of higher secondary classes who were undergoing coaching for National Science Talent Search Examination. This trial was done with one set of 6 items based on one concept 'Osmosis', the check-list (prepared for using administration) as well as the open ended approach. Open ended approach worked only up to three levels but it did help to identify some phrases and sentences which were useful in finalisation of six statements. As for the check-list method it was possible to observe that students could agree more on items testing Knowledge and Comprehension and less on Application and Synthesis. With this experience and outcome of discussions with three of my colleagues, evaluation experts in biology, the check-list was finalised. The 7th statement 'any other process' was hardly used by any of the students. It was used rarely by some students but the process indicated could be classified into one of the six categories of statements. Therefore, this additional statement was dropped at this stage. Hindi version of these statements was also rendered with the help of three Hindi knowing experts in evaluation. So both versions were cyclostyled and provided to students along with the instructions for use. The mental process check-list is given in Annexure-D.

7.3.4 MODE OF INDICATING THE PROCESS RESPONSES

Practice was given to students with the help of one set of six items, selected from the second draft of the test, not included in the final test. The check-list as stated earlier was randomly arranged so that the possibility of tallying statements (*a-f*) one for one with each set of items (1-6) is eliminated. For recording of mental processes (process responses), students were given a separate process-response recording sheet (Annexure-E) indicating the serial number of the question (1-60) against each serial number of statements (*a-f*) were to be inserted on the blank provided against each item. They were allowed to insert more than one entry if they felt that more than one entry, say b and c were suitable for an item.

Lastly, these responses pertaining to the use of mental process were analysed in terms of correspondence between the expected and the actual mental processes used to see the difference between the student-generated hierarchy and expert-generated hierarchy.

7.4 SCORING AND RECORDING THE PROCESS RESPONSES

Keeping in view the implications for scoring and analysis, the answer sheet was designed in a manner that facilitated the two operations. As is clear from the answer sheet (Appendix-C) the 60 items were arranged with their choices A, B, C, D horizontally ranging from 1 to 6, i.e., Knowledge item followed by comprehension up to evaluation at the end, based on concept No. 1. Likewise the other question numbers were arranged on different concepts. Thus column totals indicated score on each of the six objectives and row totals indicated scores on each of the 10 concepts. Provision for total score, corrected score, wrong and omitted items has been made on the sheet itself besides the identifying data of the student. Coding was done for preparation of cards in order to feed it to the computer for final statistical analysis. The final test was administered by the researcher himself in all the eight schools.

Scoring was done manually with the help of a key prepared for the purpose as shown by cross mark (×) in Appendix-C. As indicated in the test booklet instructions to the testees. The following correction formula was used to convert the raw score into correct scores :

$$\text{Corrected Score} = \text{Raw Score} - \frac{\text{Number correct}}{\text{No. of choices} - 1}$$

Choices being four in each question, 1/3 marks were deducted from the total score of each student.

Each question carried one mark. This method ensured uniform and reliable system of scoring. Data recording sheets were prepared indicating the marks obtained by each student on each objective K, C, AP, AN, S and E followed by total row score and corrected score. In case of Sample-C different types of tables were prepared indicating item-wise, the students' response against different objectives. This showed as to how many students used a particular mental process under a particular objective in attempting that item, thereby enabling the investigator to visualise different patterns in case of items pertaining to different levels of the taxonomy of objectives.

7.5 VALIDITY OF THE TEST

Since analysis of data followed by its interpretation rests on the evidence that accrues from the measuring instrument it is desirable to discuss the various steps taken to ensure reasonable validity and reliability of the test used in the validation of the taxonomy.

7.5.1 JUDGMENTAL VALIDITY

According to Davis (1964) judgmental validity is obtained by comparison of content with the test constructor's criterion, test users' criterion or layman's criterion. Thus testing of items against these criteria can provide evidence of constructor's validity, user's validity and face validity. To secure constructor's validity the following techniques were used :

(i) Keeping in view the purpose of this test and ultimate criteria as defined in the taxonomy, criterion measures were identified in terms of objectives ranging from Knowledge to Evaluation.

(ii) Such items which appear to measure the abilities implied by each criterion measure were constructed.

(iii) Obtaining opinions of judges regarding the objectives measured by different items and then comparing with the objectives as identified by the constructor. This was done with the help of 22 expert evaluators.

(iv) To motivate the students to attempt questions honestly and do their best the purpose of the test was explained. They were informed by their biology teachers that marks obtained by them were to be reported in their unit test records for internal assessment.

Therefore, the items so selected and finalised did reflect the constructs of the taxonomy and had sufficient evidence of the materials for testing what it purported to measure.

7.5.2 CONTENT-VALIDITY

Though content validity was ensured as a part of judgmental validity the concept of validity involved here was not confined only to adequate sampling of the content but was also aimed at making the subject-matter content neutral in the sense that content remaining the same, testing could be done for obtaining evidence on the six levels of the taxonomy on each concept. This purpose was achieved through the use of the same concept (content) as a basis for testing all the six objectives ranging from Knowledge to Evaluation in each set of six items. This step did provide evidence which could be safely attributed to student's score on various objectives of the taxonomy irrespective of the content. Thus validity of students' responses is taken care of by the built-in mechanism for supporting the claim of validity. Apart from the content equalisation, each item was framed on a predetermined, specific objective relating to each of the six categories of objectives. Each set of six items measured the six objectives on one to one basis. Thus deliberate attempt to frame items on each of the six objectives testing the same concept did provide the needed inferential validity based on a priori hypothesis about the constructs of the test. The two measures adopted here, when combined together did contribute to the enrichment of validity of the test.

7.5.3 DIVERGENT VALIDITY (DISCRIMINANT)

One of the empirical methods to establish validity is to correlate test scores with the criterion data available at the same time. This is done by using an available test which claims to measure the same characteristics as the experimental test measures. If indices of correlation are high and of course significant, the test constructor feels that he has satisfied one of the technical objectives in respect of validity. This is known as concurrent-validity. Contrary to this divergent validity is one which, by virtue of low correlational indices, shows that tests (K to E) though measure the same characteristics, are in fact independent with some amount of common elements. Thus they do not measure the same characteristics despite their measuring a particular global concept. However, the components which constitute the concept are divergent and hence independent. Table 11 indicates the indices of correlations for classes IX, X and XI among different objectives.

Range of indices is 0.29 to 0.60 but for three indices of .66, .67, .70, out of a total of 45 forming 3 matrices for the classes IX, X and XI i.e., 15 each. These indices though not low, are not very high either. Calculated r (range) varies from 0.38 to 0.56 in case of class IX, 0.29 to 0.59 in class X and 0.38 to 0.70 in class XI. All correlations are significant at 0.01 level.

Table 11

CLASS-WISE INTER-OBJECTIVE CORRELATION MATRIX

			Class-IX			N=321
Objectives	**K**	**C**	**AP**	**AN**	**S**	**E**
K	—	0.53	0.53	0.45	0.56	0.38
C		—	0.48	0.50	0.49	0.38
AP			—	0.45	0.54	0.53
AN				—	0.52	0.47
S					—	0.50
E						—
			Class-X			N=291
K	—	0.44	0.41	0.31	0.44	0.29*
C		—	0.52	0.43	0.56	0.45
AP			—	0.48	0.54	0.48
AN				—	0.50	0.44
S					—	0.59
E						—

Class-XI N=200

Objectives	K	C	AP	NA	S	E
K	—	0.56	0.56	0.38	0.48	0.52
C		—	0.60	0.45	0.48	0.52
AP			—	0.59	0.70*	0.66
AN				—	0.56	0.56
S					—	0.66
E						—

*Lowest (0.29) and Highest (0.70) indices.

7.5.4 ITEM VALIDITY

After the pilot tryout when second draft of 108 items was tried out on 100 students, the indices of discrimination for each item were calculated. The indices of 60 items retained for the final test ranged from 0.11 to 0.85. But for 3 items whose indices were below 0.20 (0.11, 0.15, 0.18) no item with less than 0.2 index was included. Support for retaining these items with low indices was sought from Cox's Item Selection Technique (1965) which suggests, 'the possibility of selecting the most discriminating items within a particular taxonomical category rather than selecting the most discriminating items from the total test pool'. Keeping in view the indices of the 57 out of 60 items it is quite encouraging that the test on the whole had good item validity or discriminating power. Concept-wise range of indices for the 60 items is given in the following Table 12 :

Table 12

CONCEPT-WISE INDICES OF DISCRIMINATION (FINAL TEST)

S. No of Concepts Selected	Concept	Below 0.20	0.20 to 0.29	0.30 to 0.39	0.40 to 0.49	0.50 to 0.59	0.60 to 0.69	0.70 to 0.79	Above 0.80	Total
5	I	0	2	0	1	3	0	0	0	6
7	II	1	1	0	0	3	1	0	0	6
8	III	1	1	2	1	1	0	0	0	6
9	IV	0	2	1	2	0	0	1	0	6
12	V	1	0	1	1	1	1	0	1	6
13	VI	0	0	1	2	2	0	1	0	6
14	VII	0	1	2	2	0	1	0	0	6
16	VIII	0	0	3	2	0	0	1	0	6
17	IX	0	1	0	2	1	1	1	0	6
18	X	0	0	1	2	1	0	2	0	6
No. of items Index-wise		3	8	11	15	12	4	6	1	60

7.5.5 RATERS'S AGREEMENT ON ITEMS

In the first round categorisation of 144 items (first draft) under different objectives was done by 22 raters with the help of a reference note. In the second round, classification of 108 items (second draft) was undertaken at a workshop with the help of illustrative material for practice of raters.

It may be stated that raters tend to classify items in congruence with the category behaviours provided they are properly oriented for classifying items in accordance with the behaviour they were intended to evoke. Of course, this statement has absolutely no bearing on whether the items do in fact evoke the processes they were intended to evoke.

7.6 RELIABILITY OF THE TEST

This is another important aspect influencing the behaviour of a test. As is well-known, reliability sets a ceiling to the validity of a test and, therefore, ensuring high reliability becomes essential for proceeding any further with the use of the test for testing what it is intended to test. To take care of this aspect, reasonable length of the test, (60 items), use of only multiple choice items, use of correction formula for guessing and inclusion of appropriate directions for testees to attempt questions preceded by practice items when combined with administration in all the eight schools by the investigator himself, were the measures adopted to make the test reliable.

7.6.1 SPLIT-HALF RELIABILITY

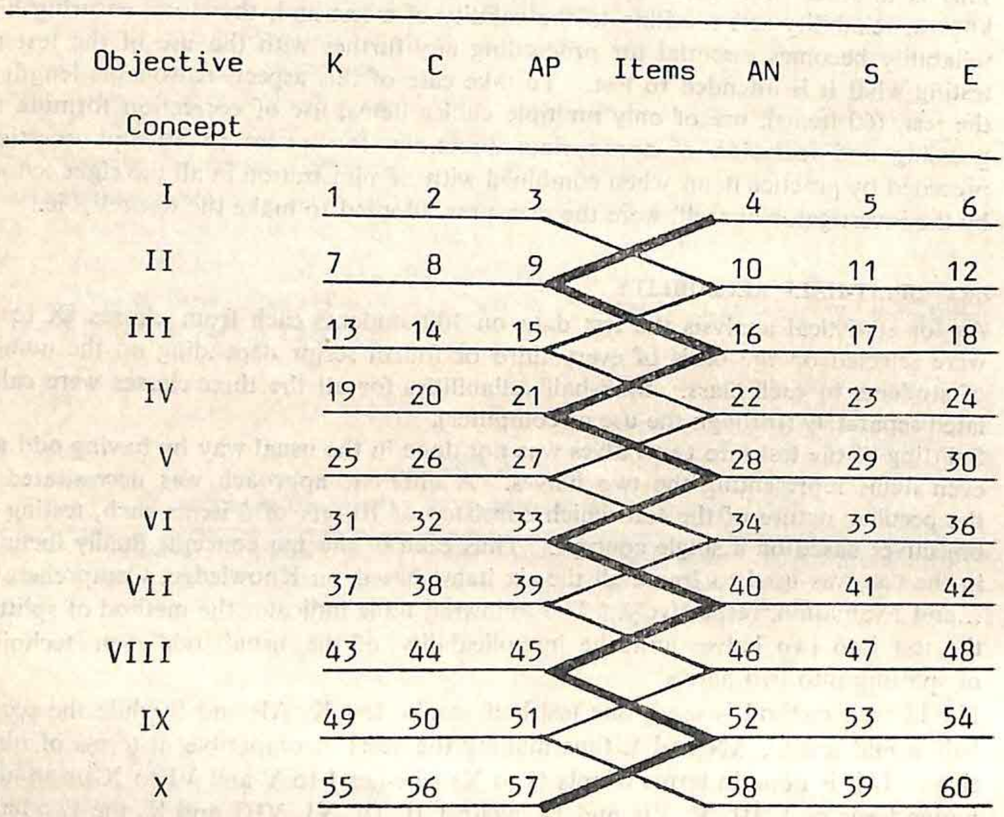
As for statistical analysis the test data on 100 students each from classes IX to XI were selected on the basis of every third or fourth script depending on the number of students in each class. Split-half reliabilities for all the three classes were calculated separately (through the use of computer).

Splitting of the test into two halves was not done in the usual way by having odd and even items representing the two halves. A different approach was necessitated by the peculiar nature of the test which consisted of 10 sets of 6 items each, testing six objectives based on a single concept. Thus each of the ten concepts finally included in the test was used to frame all the six items based on Knowledge, Comprehension ...and Evaluation, respectively. The following table indicates the method of splitting the test into two halves and the inapplicability of the usual odd-even technique of splitting into two halves.

If odd-even method is used, one test-half would test K, AP and S while the second half would test C, AN and E thus making the tests incompatible in terms of objectives. If it is done in terms of sets (I to X) whether I to V and VI to X or an alternative basis as I, III, V, VII and IX against II, IV, VI, VIII and X, the two halves would again remain non-comparable in terms of content or the concepts tested. Therefore, to ensure relative test comparability, balance and equivalence in terms of objectives as well as the content it was preferred to classify the items into two halves by allocating first three items (1-3) of a set of 6 items to one half and the remaining three (4-6) to the other half. However, the sequence of items (1-3) and (4-6) would be interchanged for each concept alternately (I-X). Therefore, the two halves used for calculating the split half reliability, are shown in Table 13 indicating by means of

Table 13

MODE OF DISTRIBUTION OF ITEMS FOR SPLIT-HALF RELIABILITY



Objective Concept	K	C	AP	Items	AN	S	E
I	1	2	3		4	5	6
II	7	8	9		10	11	12
III	13	14	15		16	17	18
IV	19	20	21		22	23	24
V	25	26	27		28	29	30
VI	31	32	33		34	35	36
VII	37	38	39		40	41	42
VIII	43	44	45		46	47	48
IX	49	50	51		52	53	54
X	55	56	57		58	59	60

arrows. The sequence of items selected for each half. Composition of the two halves is shown in the Table 14 below :

Table 14

COMPOSITION OF THE TWO HALVES OF THE TEST FOR CALCULATING RELIABILITY

Concept No.	Items in 1st half			*	Items in 2nd half		
I	1	2	3	→	4	5	6
II	12	11	10	←	9	8	7
III	13	14	15	→	16	17	18
IV	24	23	22	←	21	20	19
V	25	26	27	→	28	29	30
VI	36	35	34	←	33	32	31
VII	37	38	39	→	40	41	42
VIII	48	47	46	←	45	44	43
IX	49	50	51	→	52	53	54
X	60	59	58	←	57	56	55

* Arrows indicate sequence of items for splitting the test into two

This arrangement ensured much better equivalence of the two tests. The reliability coefficients calculated by split-half method are as under :

	IX	X	XI
r =	0.830	0.749	0.811

When corrected by the Spearman-Brown Prophecy Formula the correlations obtained were as under :

	IX	X	XI
r =	0.907	0.856	0.896

Keeping in view the nature of the test which is taxonomic in its development of items and maintenance of the content equivalence of the items, the reliability of the test as a whole is quite encouraging. It indicates high consistency of the test which in turn enables us to put our faith and confidence in the evidence that accrued from the use of this test.

7.6.2 KUDER-RICHARDSON RELIABILITY

One of the objections raised in case of split-half reliability is that the chance error may affect scores on the two halves of the test in the same way thus tending to make the reliability coefficient too high. To confirm further the reliability of the test, the method of rational equivalence was used. Since this method stresses intercorrelations of the items in the test and the correlation of the items with the test as a whole, the Kuder-Richardson Formula (20) given below was used to calculate the reliability of the test. The same sample of 100 scripts each from classes IX, X and XI were used to determine the reliability.

$$r_{11}=\frac{n}{(n-1)}\times\frac{\sigma t^2-\Sigma pq}{\sigma t^2}$$

The following reliability coefficients were found :

Class	IX	X	XI
Reliability Coefficients	0.913	0.896	0.941

The high reliability coefficients indicate evidence on intercorrelation of items in test as well as correlation of items with the test as a whole. This evidence further confirms the test reliability calculated by split-half methods, thereby making the user of the test more confident to develop faith in the evidence that accrues from the use of this test. Reliability being quite good, further analysis of data was undertaken thereafter. Detailed analysis of results and its discussion is given in the Chapter that follows.

ANNEXURE—D

MENTAL PROCESSES CHECK LIST

1. Immediately after attempting a question try to recollect as to how did you arrive at the answer.
2. To help you in this task six statements (a to f) showing different levels of mental processes are given below. Read them carefully.
3. You might have used one of these while solving the question. Choose the statement (a or b or c or d or e or f) which reflects most nearly the same mental process that you used in answering a question. Then write its Serial No. (a, b, c, d, e, f) against the serial number of the question you attempt.
4. In case you are not able to decide, you may select more than one statement if that helps you to depict more clearly the thought process you used. In that case more than one serial number may be written.
5. Write the serial number of the mental process (a to f) against the serial number of each question (1 to 60) at the blank space provided on the separate sheet supplied to you.

Which Mental Process I used to arrive at the Answer ?

a. I analysed the given situation in the question and drew logical conclusion. Then I *judged* each statement (A, B, C, D) against that conclusion to find out the one which was most adequate/relevant (applicable)/consistent (in line with).

b. I simply recalled what I had learnt and reproduced the answer from my *memory.*

c. I had to identify the concept/principle underlying the new situation given in the question. Then I *applied* (used) it to get the answer.

d. I analysed the situation given in the question and established relationship between different elements (what is given and what is required). Then *I developed the new relationship* and came to a conclusion or a generalisation by reorganising the ideas.

e. It was not possible to answer the question just from my memory I had to *understand* the biological concept or principle involved in the question, to answer it.

f. I analysed the situation given in the question to identify different elements (what is given and what is required). Then I found but the relationship between them or also the basis of those relationships.

ANNEXURE—E

PROCESS RESPONSE RECORDING SHEET

(Biology Achievement test)

Write a, b, c, d, e or f against each of the questions 1-60 on the blank provided :

Q. No.	*Q. No.*	*Q. No.*	*Q. No.*	*Q. No.*	*Q. No.*
1.——	2.——	3.——	4.——	5.——	6.——
7.——	8.——	9.——	10.——	11.——	12.——
13.——	14.——	15.——	16.——	17.——	18.——
19.——	20.——	21.——	22.——	23.——	24.——
25.——	26.——	27.——	28.——	29.——	30.——
31.——	32.——	33.——	34.——	35.——	36.——
37.——	38.——	39.——	40.——	41.——	42.——
43.——	44.——	45.——	46.——	47.——	48.——
49.——	50.——	51.——	52.——	53.——	54.——
55.——	56.——	57.——	58.——	59.——	60.——

8

8.0 VALIDATING THE HIERARCHY OF OBJECTIVES

The first tangle to be solved in analysing the data was, whether to use the parametric or non-parametric devices. It has already been discussed in Chapter IV that non-normality of the frequency distribution and the skewed nature of the distributions cast doubt on the use of parametric devices as one of the assumptions of parametric tests would have to be violated. Moreover, the most commonly used educational data are measured on scales which are not as strong as the interval scale. Writers like Siegel (1956) argue that, "unless data have been measured on a scale of at least interval length, parametric techniques such as analysis of variance should not be used."

According to other statisticians as reported by Popham (1967), this viewpoint is strongly rejected by statisticians on the ground that

> "it confuses a measurment question with a statistical question. It is not true that parametic analysis such as 't' test cannot be computed on data which are only ordinal in nature. Actually parametric procedures can be computed whenever the data are presented in numerical form. A number of empirical studies have demonstrated, that when parametric procedures have been employed with ordinal data they rarely distort a relationship between variables which may be present in the data."

8.1 A CASE FOR USING PARAMETRIC METHODS

In the present study parametric techniques are used despite the weakness of skewed distribution of data. Reasons for this are many. One, they provide more analysis flexibility, as for example, the use of the analysis of variance. Two, a parametric procedure is more powerful than its non-parametric counterpart. It would more frequently reject a null hypothesis than will a non-parametric test designed to perform the same function. Three, its strength lies in the use of more of available information such as the deviations from the mean of scores in the analysis, in contrast to non-parametric methods which depend on frequency count and ranking procedures disregarding much of the information available in the data. Four, the sample is quite large, i.e., 812 students. Even class-wise the sample is large, i.e., 321, 291, 200 for class IX, X and XI. So pattern of analysis will remain the same.

Distributions over the objectives are not indicative of normality, an assumption of parametric methods. One major reason is that compared to means of the various distributions, school-wise or class-wise, standard deviations are so large that it is only through parametric statistics that full information embedded in the scores can be utilised. Class-wise means and standard deviations are given below in Table 15.

Table 15

CLASSWISE MEANS AND STANDARD DEVIATIONS

Statistic	IX	X	XI
Mean	15.302	21.421	30.420
Standard Deviation	11.584	10.486	12.663

The picture with respect to means and standard deviations of scores from the eight schools is almost similar. In all the three classes, the standard deviation compared to mean is very large. In 18 out of 144 cases S.D. is even larger than the corresponding mean. Class-wise means and standard deviations over the six objectives are shown in Table 16.

Table 16

CLASS-WISE MEANS AND STANDARD DEVIATIONS ON DIFFERENT OBJECTIVES

Objective	Statistic	Class IX	Class X	Class XI
1. Knowledge	Mean	4.53	5.97	7.37
	S.D.	2.69	2.30	2.47
2. Comprehension	Mean	3.10	3.98	5.92
	S.D.	2.25	2.31	2.53
3. Application	Mean	1.92	2.78	4.38
	S.D.	2.38	2.21	2.85
4. Analysis	Mean	2.32	2.75	4.30
	S.D.	2.25	2.14	2.51
5. Synthesis	Mean	3.14	4.01	5.54
	S.D.	2.70	2.56	2.82
6. Evaluation	Mean	1.53	2.31	3.40
	S.D.	1.92	2.07	2.44

From the table it is quite clear that standard deviations are so large that it is not desirable to ignore this fact and use non-parametric methods. Since parametric techniques can utilise better the information that is reflected in the large standard deviations of scores, its application in preference to non-parametric methods was considered more appropriate to analyse the data.

Data were tabulated into frequency distributions and represented in the form of frequency polygons. Means and standard deviations of scores on different objectives in different classes and for various schools were calculated. Null hypothesis were framed and tested. Analysis of data and discussion of results are given below :

8.2 TESTING OF HYPOTHESIS—I

H : 1 There is no significant difference among different levels of learning, categorised in the taxonomy as Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation.

To test this hypothesis following techniques were employed :

8.2.1 Study of the graphical curves of frequency polygons
8.2.2 Significance of difference in mean of score on different objectives
8.2.3 Bivariate distribution of scores
8.2.4 Logic of the taxonomic test
8.2.5 Inferential evidence from experts' judgment

8.2.1 STUDY OF THE GRAPHICAL CURVES OF FREQUENCY POLYGONS

It is already mentioned in Chapter VI that the data were gathered from 812 students of different schools, studying in classes IX, X and XI. The data are the achievement-scores on the post-test of 60 marks divided equally on the six taxonomical objectives i.e., Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. First of all data were grouped into school-wise frequency distributions on 0-10 scale, over the six objectives. Since 10 items on each of the 6 objectives were included, one on each concept the maximum score a student could get was 10 and minimum as zero.

Apart from school-wise distribution a chart for all the 8 schools was prepared according to objective-wise scores, for the three classes on the same interval scale of 0-10. These frequency distributions were then graphically represented in the form of frequency polygons for the six objectives for classes IX, X and XI.

One of the evidences that throws light on this hypothesis is the distribution of scores and shape of curves of the frequency polygons and the histograms. Observation of the shape of the 18 graphs, 5 for each (superimposed of the three classes IX, X, and XI reveal by and large skewed nature of the distributions as seen in Figs. 4, 5 and 6. Shape of curves indicate greater density of scores towards the left (lower objective like K) and the gradual shift from the negatively skewed to the positively skewed nature of these curves as we move from lowermost objective, 'Knowledge' to the most complex one, 'Evaluation'. Position of the 'Analysis' category in class IX graphs and the Synthesis in all the three classes, however, seems to be not in line with the complexity of objectives. The trend of the simple graphs of frequency distributions, in general appear to support the assumption of hierarchical structure of achievement. Barring the category of Synthesis the negligible low frequencies in the uppermost continuum of achievement, i.e., Evaluation, indicates complex and the difficult nature of the abilities involved in solving problems pertaining to these levels.

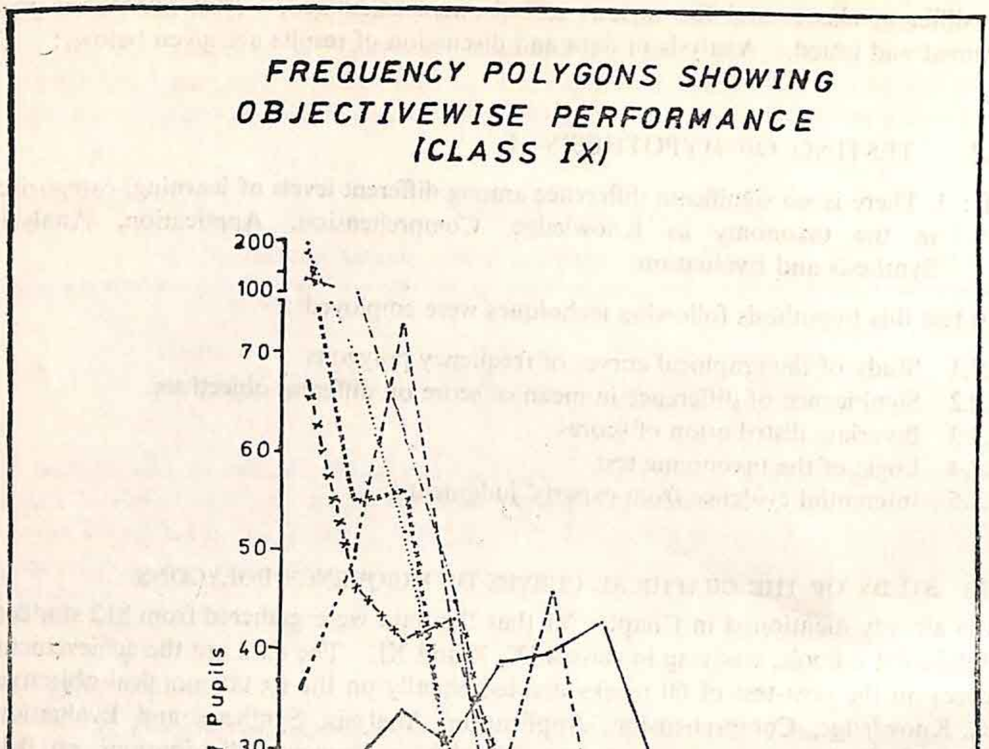

FREQUENCY POLYGONS SHOWING
OBJECTIVEWISE PERFORMANCE
(CLASS IX)
200
100
70
60
50
40
30
20
10
0
Number of Pupils
0
1
2
3
4
5
6
7
8
9
10
Scores
Knowledge
Comprehension
Application
Analysis
Synthesis
Evaluation

Fig. 4

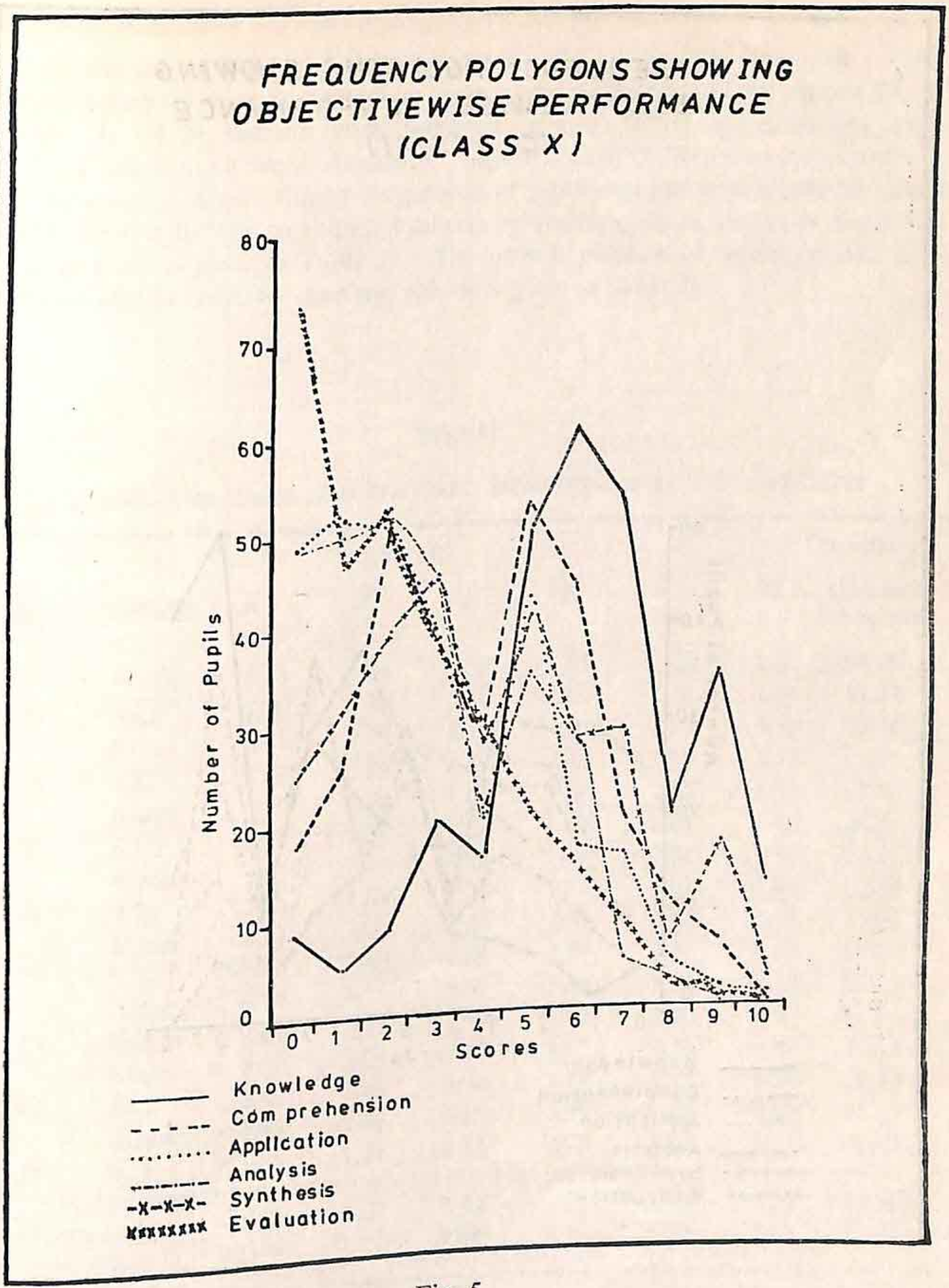

FREQUENCY POLYGONS SHOWING OBJECTIVEWISE PERFORMANCE (CLASS X)
Number of Pupils
0
10
20
30
40
50
60
70
80
Scores
0
1
2
3
4
5
6
7
8
9
10
Knowledge
Comprehension
Application
Analysis
Synthesis
Evaluation

Fig. 5

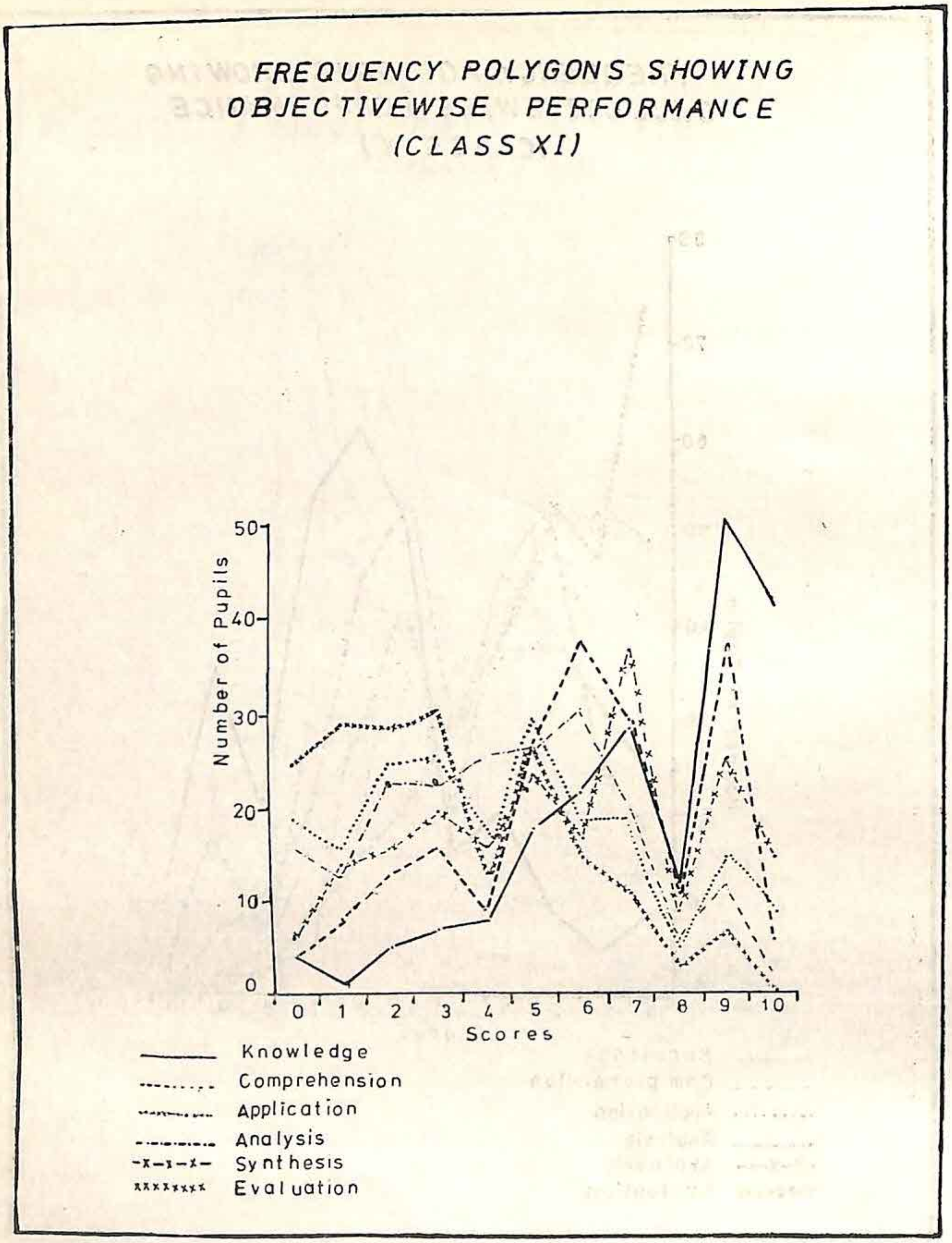

FREQUENCY POLYGONS SHOWING
OBJECTIVEWISE PERFORMANCE
(CLASS XI)
Number of Pupils
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
Scores
Knowledge
Comprehension
Application
Analysis
Synthesis
Evaluation

Fig. 6

8.2.2 SIGNIFICANCE OF DIFFERENCE IN MEAN SCORE ON DIFFERENT OBJECTIVES

Difference in means was calculated from Table 17, 18 and 19, values of 't' for different objectives were computed for each of the eight schools for classes IX, X and XI. In all 24 matrices were prepared showing differences in means (DM) and the 't' values as shown in Annexure. Significance of difference in the means was observed using 't' table. Class-wise position of significant and non-significant values of critical ratios for the combined 8 schools representing three classes in respect of all the 15 pairs is given in Table 20. The overall position of significant and non-significant critical ratios for the three classes is given in Table 21.

Table 17

SCHOOL-WISE MEANS AND STANDARD DEVIATIONS OVER THE OBJECTIVES

		CLASS IX						N=321
School No.	Statistic	K	C	AP	AN	S	E	Combined School-wise
1.1	Mean	4.78	3.24	1.88	2.29	2.88	1.20	14.59
df=75	S.D.	2.70	2.36	2.10	2.00	2.61	1.64	11.12
2.1	Mean	6.81	4.47	4.16	4.94	6.37	3.50	30.59
df=31	S.D.	2.08	2.19	2.29	2.15	2.55	2.55	09.26
3.1	Mean	3.97	2.76	1.03	1.88	2.12	1.09	11.68
df=33	S.D.	1.90	2.06	1.38	1.54	2.01	1.22	06.80
4.1	Mean	3.83	2.93	0.93	1.88	2.21	1.26	11.11
df=41	S.D.	2.22	1.68	1.24	1.97	1.98	1.94	07.63
5.1	Mean	4.17	3.00	1.66	2.31	4.10	1.38	15.72
df=28	S.D.	2.50	2.40	1.68	2.57	2.32	1.60	10.17
6.1	Mean	6.19	4.56	3.67	3.56	5.00	2.53	25.22
df=35	S.D.	2.53	2.51	2.40	2.49	2.50	2.07	11.87
7.1	Mean	4.16	2.09	1.42	1.05	2.26	0.93	10.14
df=42	S.D.	2.43	1.49	3.34	1.28	1.78	1.26	6.19
8.1	Mean	1.83	1.66	0.83	0.97	0.79	0.90	05.52
df=28	S.D.	1.86	1.21	0.95	0.96	1.03	1.21	05.73
Combined	Mean	4.53	3.10	1.92	2.32	3.14	1.53	15.302
Objective-wise	S.D.	2.69	2.25	2.38	2.25	2.70	1.02	11.593

K—Knowledge
C—Comprehension
AP—Application

AN—Analysis
S—Synthesis
E—Evaluation

1—IX School No. 1
2—X School No. 2
3—XI School No. 3

Table 18

SCHOOL-WISE MEANS AND STANDARD DEVIATIONS OVER THE OBJECTIVES

School No.	Statistic	CLASS X K	C	AP	AN	S	E	N=291 Combined School-wise
1.2	Mean	5.97	4.22	2.82	2.59	3.77	2.33	21.27
df=72	S.D.	2.37	2.46	2.24	1.96	2.50	1.97	10.62
2.2	Mean	7.25	5.46	3.71	3.43	6.07	2.79	28.32
df=27	S.D.	1.45	1.82	1.91	2.23	1.89	1.99	07.96
3.2	Mean	4.42	2.64	1.39	1.97	2.92	2.06	14.83
df=35	S.D.	2.35	2.06	1.81	1.82	2.51	2.05	10.15
4.2	Mean	6.19	4.59	2.67	2.62	4.33	3.07	23.48
df=26	S.D.	2.21	1.83	2.40	2.05	2.57	2.73	11.29
5.2	Mean	6.20	3.83	2.63	2.73	3.43	1.40	19.63
df=29	S.D.	1.83	2.11	2.17	2.19	2.60	1.69	08.42
6.2	Mean	6.36	5.03	4.18	3.76	5.79	2.76	27.70
df=32	S.D.	1.84	2.20	2.56	2.36	2.32	2.20	10.42
7.2	Mean	5.95	3.36	2.64	2.64	3.60	2.38	19.92
df=41	S.D.	2.58	1.93	1.62	2.31	1.88	1.75	08.05
8.2	Mean	5.73	2.59	2.27	2.55	2.50	1.59	17.36
df=21	S.D.	2.14	1.97	1.48	1.59	1.88	1.67	08.09
Combined	Mean	5.97	3.98	2.78	2.75	4.01	2.31	21.429
Objective-wise	S.D.	2.30	2.31	2.22	2.14	2.56	2.07	10.486

Table 19

SCHOOL-WISE MEAN AND STANDARD DEVIATIONS OVER THE OBJECTIVES

School No.	Statistic	K	C	CLASS XI AP	AN	S	E	N=200 Combined School-wise
1.3	Mean	6.89	7.17	5.50	5.00	6.67	3.61	34.94
df=17	S.D.	2.64	2.39	2.71	2.31	2.89	2.43	12.15
2.3	Mean	8.65	7.31	6.23	5.96	7.77	4.58	40.53
df=25	S.D.	1.44	1.90	2.21	1.83	1.34	2.47	07.70
3.3	Mean	6.95	5.44	3.20	3.12	3.12	2.59	23.59
df=40	S.D.	2.81	2.69	2.60	2.04	2.51	2.59	12.25
4.3	Mean	6.81	4.73	3.81	4.08	5.62	3.38	26.80
df=25	S.D.	2.60	2.36	2.84	2.67	2.39	2.53	12.62
5.3	Mean	6.56	5.08	3.50	3.46	4.77	2.58	25.65
df=47	S.D,	2.20	2.34	2.24	2.29	2.27	2.08	09.00
6.3	Mean	8.78	7.44	6.17	6.44	7.89	5.28	41.56
df=17	S.D.	1.31	2.39	2.24	2.43	2.20	2.08	09.48
7.3	Mean	8.50	7.63	6.50	5.88	7.88	5.25	40.88
df=7	S.D.	2.50	1.58	3.71	1.83	2.52	1.98	12.50
8.3	Mean	8.13	5.33	3.60	3.47	5.13	2.73	28.73
df=14	S.D.	2.16	1.35	2.78	1.71	1.63	1.91	08.68
Combined	Mean	7.37	5.92	4.38	4.30	5.54	3.40	30.420
Objective-wise	S.D.	2.47	2.53	2.85	2.51	2.83	2.44	12.663

Table 20

CRITICAL RATIOS SHOWING SIGNIFICANCE OF DIFFERENCE AMONG MEANS OF DIFFERENT OBJECTIVES

	Class	df=320	IX	N=321	df=290	X	N=291	df=199	XI	N=200
Sl. No.	Objective pair	Mean Diff M.D.	S.E.D S.E.D	C.R. C.R.	M.D.	S.E.D	C.R.	M.D.	S.E.D	C.R.
1.	K-C	1.43	0.1378	10.38	1.99	0.1483	13.42	1.45	0.1631	08.89
2.	K-AP	2.61	0.1378	18.94	3.19	0.1469	21.72	2.99	0.1951	15.33
3.	K-AN	2.21	0.1303	16.96	3.22	0.1587	20.29	3.07	0.1950	15.74
4.	K-S	1.39	0.1449	09.59	1.96	0.1536	12.76	1.83	0.1905	09.61
5.	K-E	3.00	0.1483	20.23	3.66	0.1609	22.75	3.97	0.1664	23.86
6.	C-AP	1.18	0.1342	08.79	1.20	0.1327	09.04	1.54	0.1709	09.01
7.	C-AN	0.78	0.1265	06.17	1.23	0.1442	08.53	1.62	0.1857	08.72
8.	C-S	—0.04	0.1414	00.28*	—0.03	0.1364*	00.22	0.38	0.1849	02.06**
9.	C-E	1.57	0.1342	11.70	1.67	0.1375	12.15	2.52	0.1786	14.11
10.	AP-AN	—0.37	0.1378	02.68	0.03	0.1327*	00.22	0.05	0.1729	00.29*
11.	AP-S	—1.22	0.1378	03.92	—1.23	0.1353	09.09	—1.16	0.1549	07.48
12.	AP-E	0.39	0.1183	03.30	0.47	0.1439	03.27	0.98	0.1549	06.33
13.	AN-S	—0.82	0.1414	05.80	—1.26	0.1411	08.93	—1.24	0.1792	06.92
14.	AN-E	0.79	0.1265	06.25	0.44	0.1170	03.76	0.90	0.1643	05.48
15.	S-E	1.61	0.1304	12.35	1.70	0.0872	19.50	2.14	0.1549	13.82

$$SE_D = \sqrt{SE_{M_2}^2 + SE_{M_2}^2 - 2r_{12}SE_{M_1}SE_{M_2}}$$

*Not significant
**Significant at 0.05 level

CR at 0.01=2.58
CR at 0.05=1.90

Table 21

OVERALL POSITION OF SIGNIFICANT AND NON-SIGNIFICANT C-RS CLASS-WISE

Class	IX	X	XI	Total
Number significant	79	73	71	223
Number non-significant	41	47	49	137
Total	120	120	120	360

From these data it is clear that difference are significant in at least 60% of the cases while they are not significant in the remaining 40% cases. For our purpose, more important analysis is that of the 137 non-significant ones. Position of these matrices is clearer if we observe the frequency of non-significant and significant correlations, when combined for the 8 schools, among different pairs of objectives for the three classes separately as shown on page 106.

Out of every 8 counts (i.e., for one class) or 24 (i.e., 3 classes together) the frequency of non-significant and significant values, were examined to judge the relationship among each one of the 6 objectives.

(i) KNOWLEDGE AND OTHER CATEGORIES

When combined for the three classes, out of 24, only 4 correlations are not significant for K-C, 2 for K-AP, none for K-AN, 7 for K-S and none for K-E. Therefore, out of total of 120 (8×5×3) correlations only 13 are non-significant. Of the 13 there are 7 which pertain to K-S relationship. Position of synthesis is, therefore, intriguing. It appears to have functioned almost at the comprehension level. Therefore, hardly 10% non-significant correlations including the ones with the category of synthesis whose behaviour is doubtful, is quite indicative of the independence of knowledge objective as a distinct category.

Table 22

CLASS-WISE FREQUENCY OF SIGNIFICANT AND NON-SIGNIFICANT DIFFERENCES BETWEEN PAIRS OF OBJECTIVES

* Figure within brackets indicates total while figure below these are S. No. of Schools (1 to 8)

Objectives		IX N=321		X N=291		XI N=200	
Sl. No.	Pair of objectives	Significant	Non-significant	Significant	Non-significant	Significant	Non-significant
(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	(*h*)
1.	K-C	6	(2) 5,8	8	—	6	(2) 1,7
2.	K-AP	8	—	8	—	6	(2) 1,7
3.	K-AN	8	—	8	—	8	—
4.	K-S	5	(3) 2,5,6	7	(1) 6	5	(3) 1,6,7
5.	K-E	8	—	8	—	8	—
							(13/120)
6.	C-AP	5	(3) 2,6,7	5	(3) 6,7,8	4	(4) 2,4,6,7
7.	C-AN	5	(3) 2,5,6	4	(4) 3,5,7,8	5	(3) 4,6,7
8.	C-S	2	(6) 1,3,4,5,6,7	0	(8) 1 to 8	1	(7) 1,2,4,5,6,7,8
9.	C-E	7	(1)	6	(2) 3,8	7	(1) 4
							(45/96)
10.	AP-AN	2	(6) 1,2,5,6,7,8	0	(8) 1 to 8	0	(8) 1 to 8
11.	AP-S	—6	(2) 7,8	—6	(2) 5,8	—5	(3) 3,7,8

(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	(*h*)
12.	AP-E	5	(3) 5,7,8	2	(6) 1-4,7,8	4	(4) 4,6,7,8 (42/72)
13.	AN-S	2	−(6) 1,2,3-5,6,8	5	−(3) 3,5,8	4	−(4) 1,3,6,7
14.	AN-E	3	(5) 4,5,6,7,8	1	(7) 1-4,6-8	2	(6) 1,3,4,6,7,8 (31/48)
15.	S-E	7	(1) 8	5	(3) 3,4,8	6	(2) 3,7 (6/24)
Totals		79	41	73	47	71	49
Class-wise Total		120		120		120=360	

** Fraction in the last column indicates the proportion of non-significant correlations combined for the 3 classes.

This is supported by the evidence on the mean difference which goes on increasing (except for synthesis) when compared with Comprehension, Application, Analysis, Synthesis and Evaluation. All these are in positive direction. This means that 'Knowledge' category is at the bottom of all the categories.

(ii) COMPREHENSION AND OTHER CATEGORIES

Out of every 24 classes, the frequency of non-significant one is 10 for C-AP, 10 for C-AN, 21 for C-S and 4 for C-E. Thus out of a total of 96, there are 45 or about 50% non-significant coefficients. In case of C-S relationship, therefore, when 21 out of 24 values are non-significant, it is most likely that 'Synthesis' has functioned at almost the same level as the 'Comprehension'. As for relationship between C-AP and C-AN the distinction is not so well marked as in C-E relationship. Similar evidence is observed with regard to the mean differences. There is clear-cut increase in case of C-E whereas in case of C-AN, it either remained almost the same or decreased in the one case. In C-S it has invariably decreased to the extent that there is practically no difference between the two. It is also supported by the low and non-significant 't' values. In class X it is even negative. Thus it is only C-AP where 14 out of 24 values are significant and difference in means is appreciable. The independence of C-E relationship stands out markedly, thereby claiming their distinct position in the hierarchy.

(iii) APPLICATION AND OTHER CATEGORIES

Out of 42 non-significant cases there are 22 for AP-AN, 7 for AP-S (−ve) and 13 for AP-E. The overall frequency for all classes is 42 out of 72, i.e., a little above 70%. This goes to show that in general this category is markedly different from other categories. With regard to AP-AN, 22 out of 24 values are not significant. Difference in means is negative in one case (—0.37) and negligible in the other two cases, i.e., 0.03 and 0.05 (Table 20, S.No. 10) which again supports the view that Analysis has not come out as a category distinct from that of Application. Like C-S these two categories AP-AN appear to merge with each other as they seem to measure the same abilities. This is also corroborated by the insignificant C.R. of AP-AN. Apparently the 17 cases which may have significant correlations between AP-S category is indeed deceptive as it is in negative direction. 'Synthesis', having failed to come out at higher level than 'Application', functioned at a much lower level, almost equivalent to that of Comprehension. Almost the same frequency (21 out of 24) between C-S as compared to AP-S (17 being –ve out of 24) is observable. It clearly indicates that Application is higher level category than Synthesis.

In AP-E relationship out of 24 there are 13 non-significant correlations which do indicate the possibility of independence of the two categories. C.R. of AP-E (6.33) being significant (Table 20) at 0.01 level supports this view. However, low frequency of significant values (11 out of 24) does not warrant at present to pass judgment about clear independence of its character. Difference in means though small (0.98), yet it is more than that of the other two categories, AP-AN (0.05) and AP-S (—1.16). This evidence and the significant C.R. go to prove that at least 'Evaluation' is a higher level category than that of 'Application'.

(iv) ANALYSIS AND OTHER CATEGORIES

Out of 24 values 13 are non-significant in AN-S (besides being negative) and 18 in case of AN-E. Thus 31 out of 48 values i.e., about 60% are not significant. Mean difference between AN-S is significant but in negative direction because of Synthesis having behaved at the level of almost Comprehension. Therefore, claim of Analysis as a category separate from that of Synthesis does not hold good in Bloom's hierarchy where Synthesis is placed at a higher level category of objective as the latter has functioned at a much lower level.

As for AN-E relationship 18 out of 24 cases being significant again cast doubt on its independent existence as a category. When analysed in terms of relationship between AN-AP and AN-E it appears as if Analysis may be an ability or a combination of abilities which are prerequisite to 'Application' as well as 'Evaluation' objectives.

(v) SYNTHESIS AND EVALUATION

The last relationship of S-E is again misleading. The tabulated data show that only 6 out of 24 are non-significant values. The significant difference in the means as shown by critical ratios is an additional evidence which on the face of it support the independence of the two objectives. But in reality this is again deceptive because Synthesis, as already depicted in earlier discussions, functioned only at the Comprehension level. Therefore, the relationship of independence as shown by the significant values (18 out of 24) is indeed the same relationship as that of C-E where 20 out of 24 values are significant. Therefore, Evaluation category, if it stands clearly marked out, is due to the marked difference in the distance of the two categories (S-E or C-E).

From the foregoing discussion it can be inferred that the first three categories of Knowledge, Comprehension and Application are quite distinctive and independent as far as hierarchy is concerned. However, when we move from simple to the more complex objectives in the hierarchy there appears to be more and more diffusion of abilities and picture is not very clear. Nevertheless, the 'Evaluation' category also appears distinct, and higher in hierarchy than Application and Analysis.

If Synthesis and Analysis categories are not considered, the null hypothesis of no difference existing between the different categories of objectives is rejected thereby tending support to the theoretical assumptions of difference existing among them. Systematic and consistent decrease in the mean value of different objectives vindicates the position that $E > AP > C > K$ which is due to the complexity and difficulty of mental processes involved in solving the problems.

8.2.3 BIVARIATE DISTRIBUTION OF SCORES

One of the techniques used to determine the hierarchical nature of the taxonomy was to prepare graphs showing bivariate distribution of scores over the different objectives. This was done for all the 15 different types of combination of the inter-objective scores. The scattergrams of bivariate distribution are shown in figure 7 (A-O).

A plausible model according to Kropp, Stoker and Bashaw (1966) would be :

> "That score pairs are more likely to occur with greater frequency along the diagonal of the scattergram and the frequency should tend to taper off toward the extreme ends of the diagonal and away from the diagonal. Such a model might look like joint bivariate normal bell shaped distribution with one half of it missing".

Only class XI data used for calculating reliability coefficient (100 out of 200 students) were used in this case. The position is as under :

8.2.3.1 TOTAL HIERARCHY K-E

There appears no clear picture of K with C as about 35% scores lie above the diagonal. Hierarchy is more clearly observable in case of C with AP. With respect to AP and AN there seems to be almost complete overlap and the two seem to be merging with each other. With regard to AN-S the hierarchy is reversed showing thereby a lower position of S than that of AN. In respect of S-E hierarchy is quite distinct, like the one with Comprehension.

Therefore, but for the position of K and E the position of other objectives appears to be not in conformity with the expected hierarchy.

(i) KNOWLEDGE AND OTHER CATEGORIES

When 'Knowledge' is taken with other categories, the position of hierarchy is as follows :

The distribution of scores does not show a distinctly marked hierarchy with Comprehension as about 35% of the scores lie above the diagonal indicating that C is not distinctly higher than Knowledge. With respect to Application the hierarchy is more distinct since hardly about 10% scores lie above the diagonal. Position with respect to Analysis is similar to that of Application. With respect to Synthesis

BIVARIATE DISTRIBUTION OF SCORES ON DIFFERENT OBJECTIVES (CLASS XI)

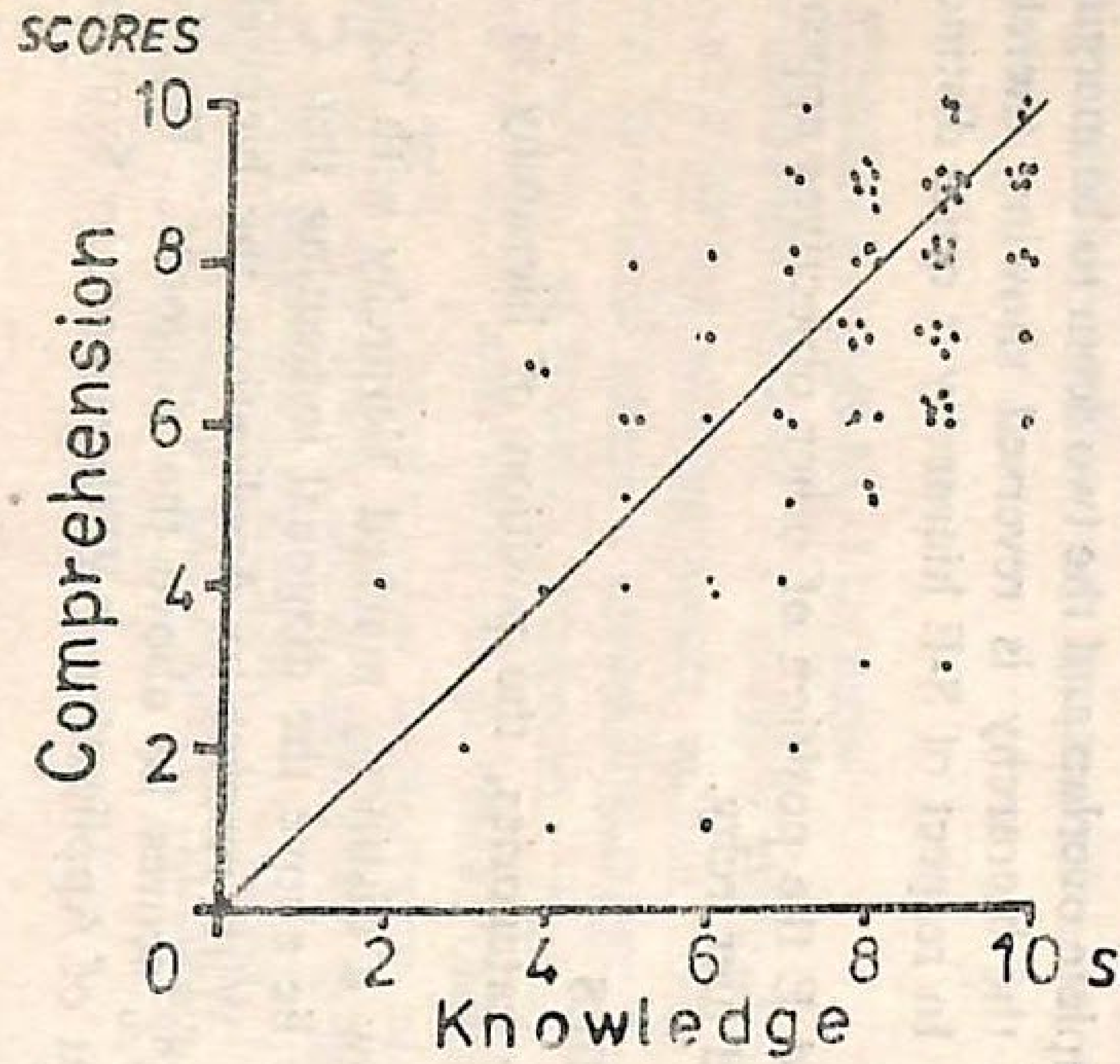


Fig. 7A

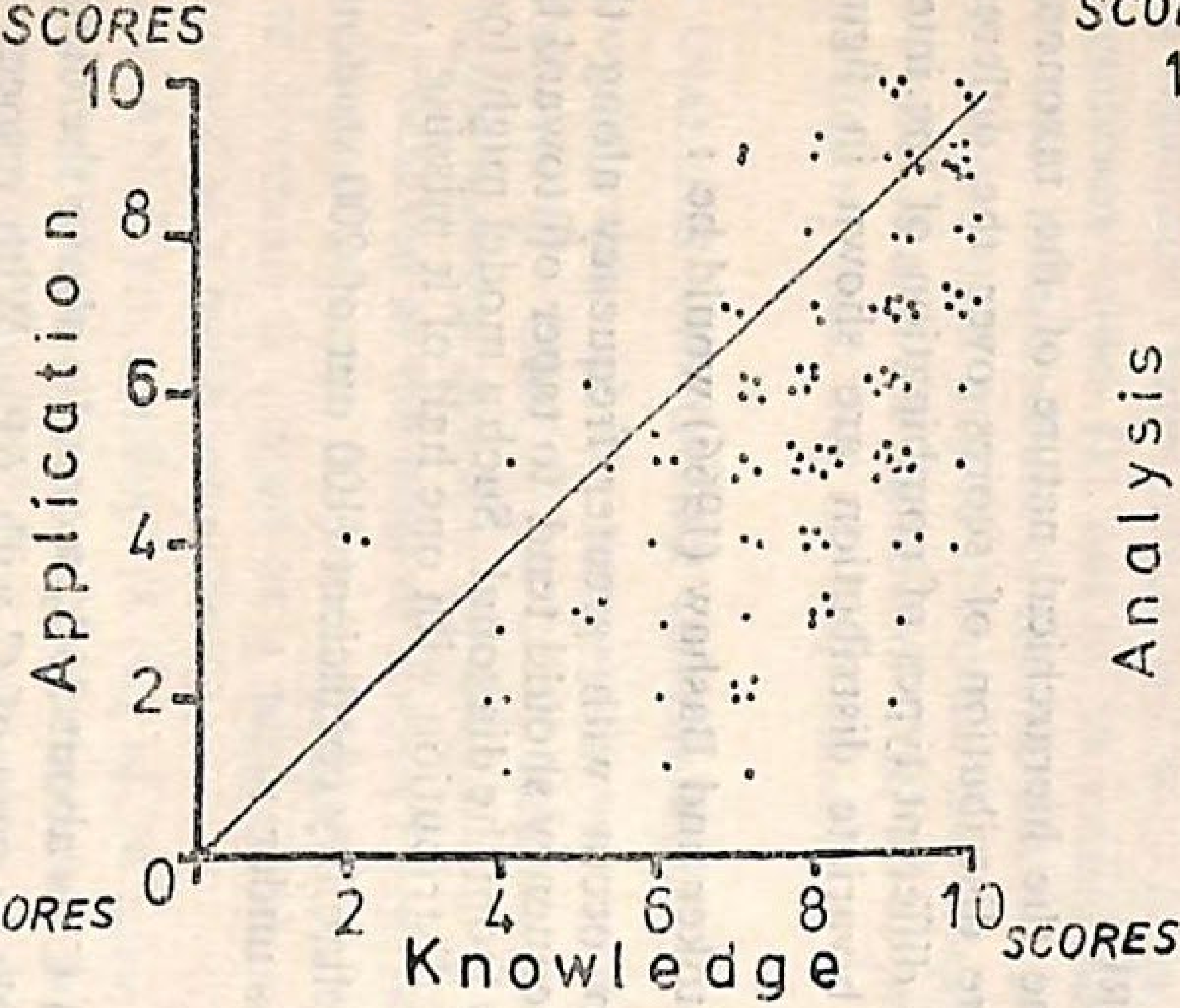


Fig. 7B

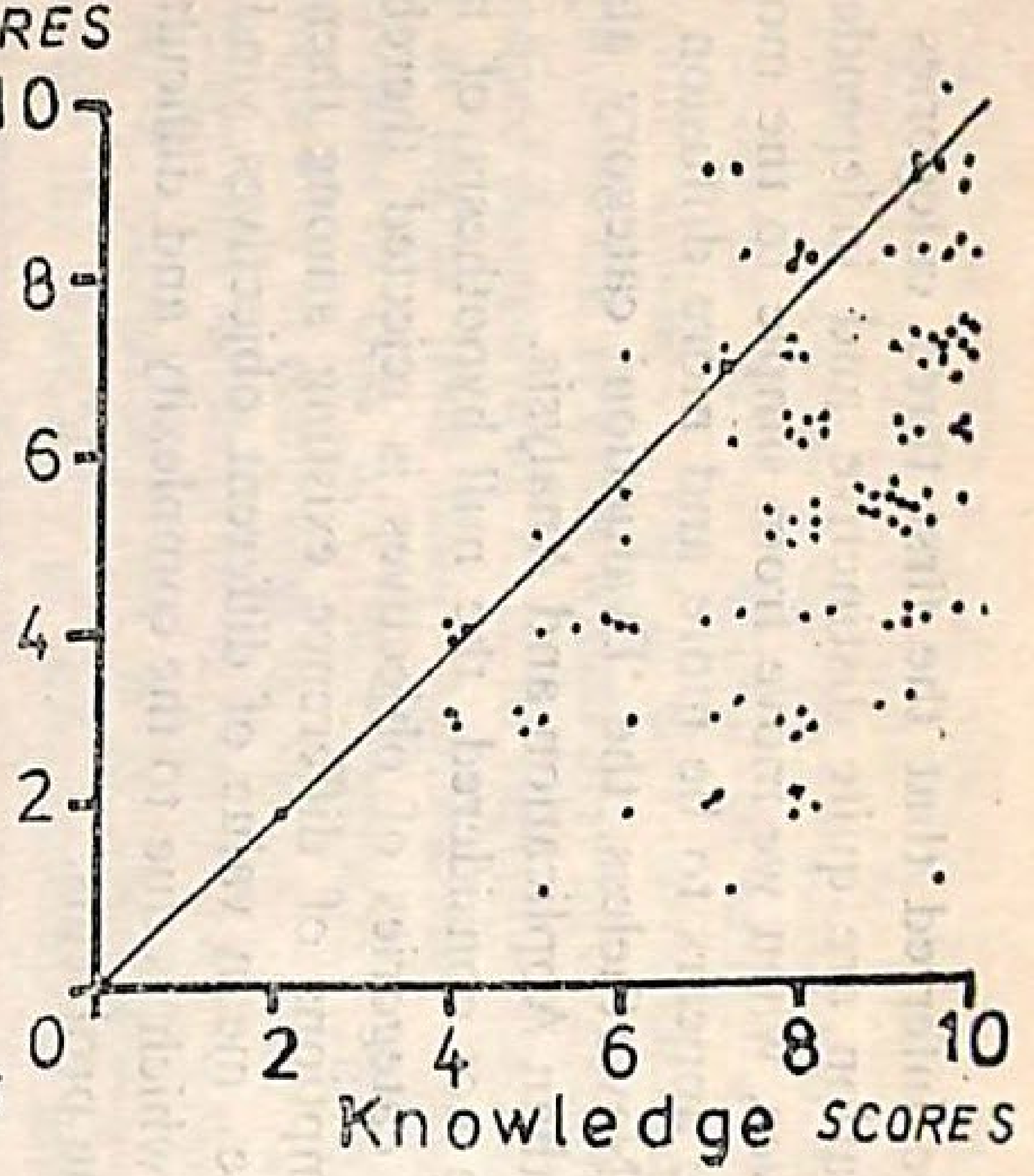


Fig. 7C

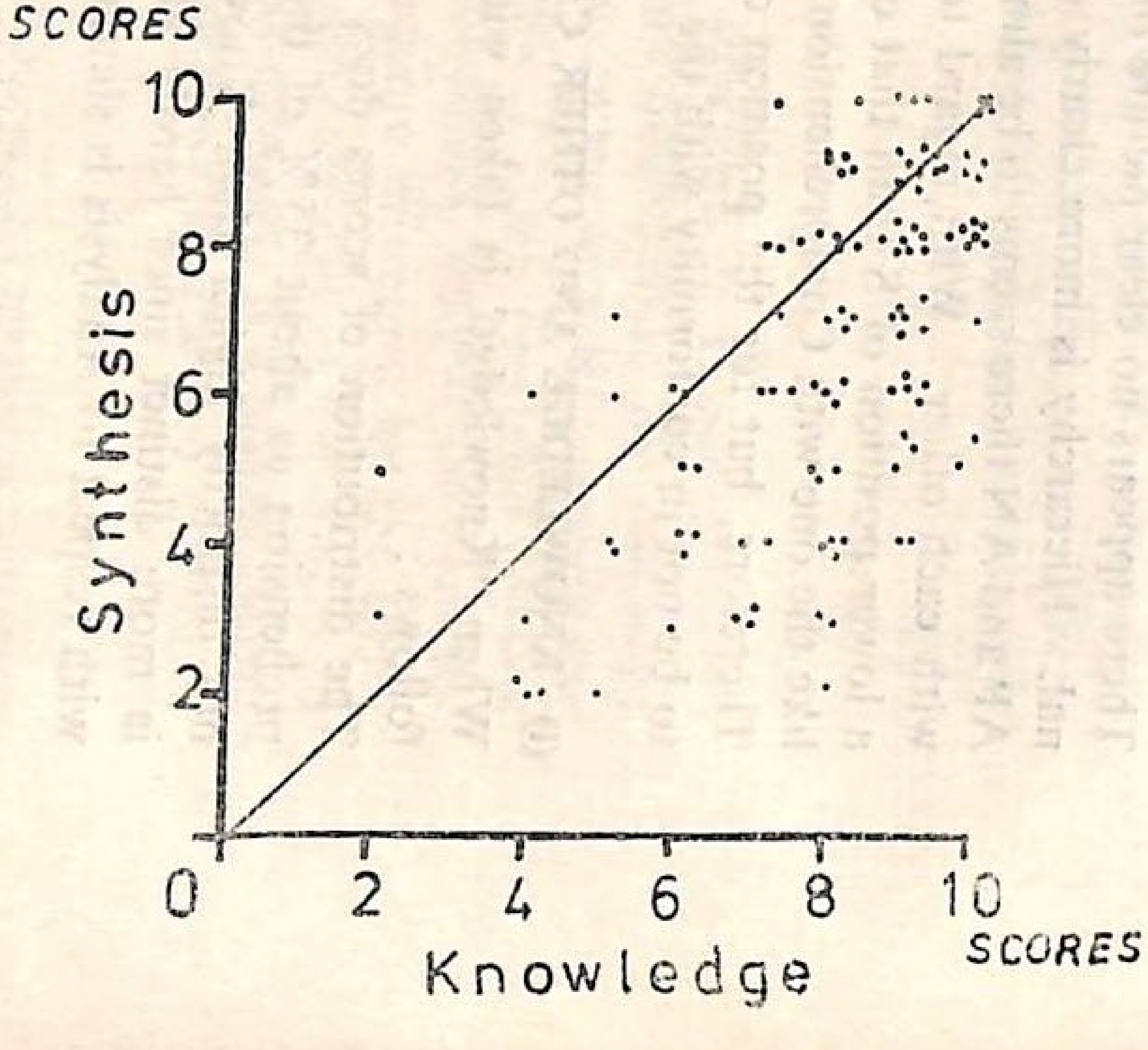


Fig. 7D

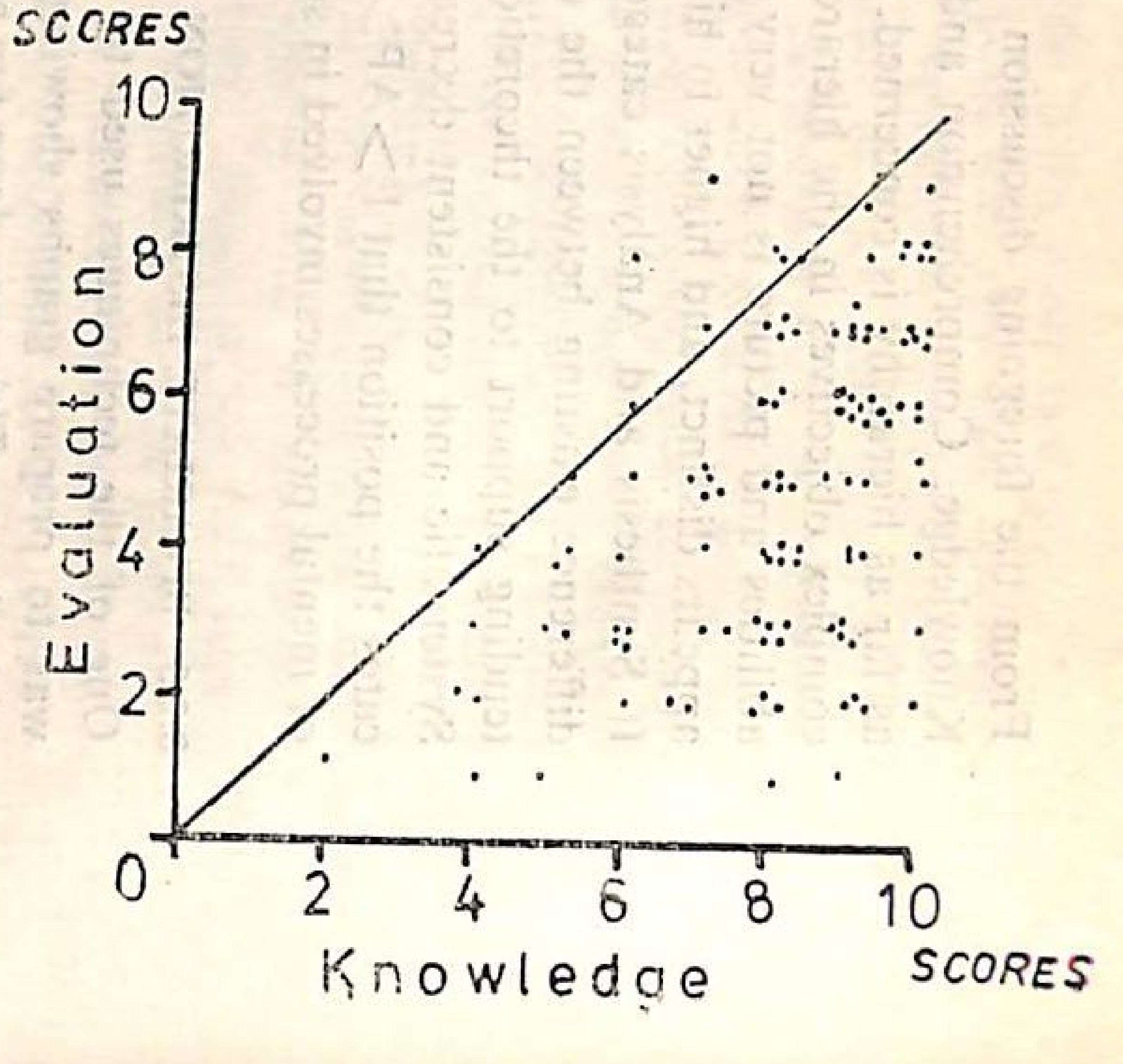


Fig. 7E

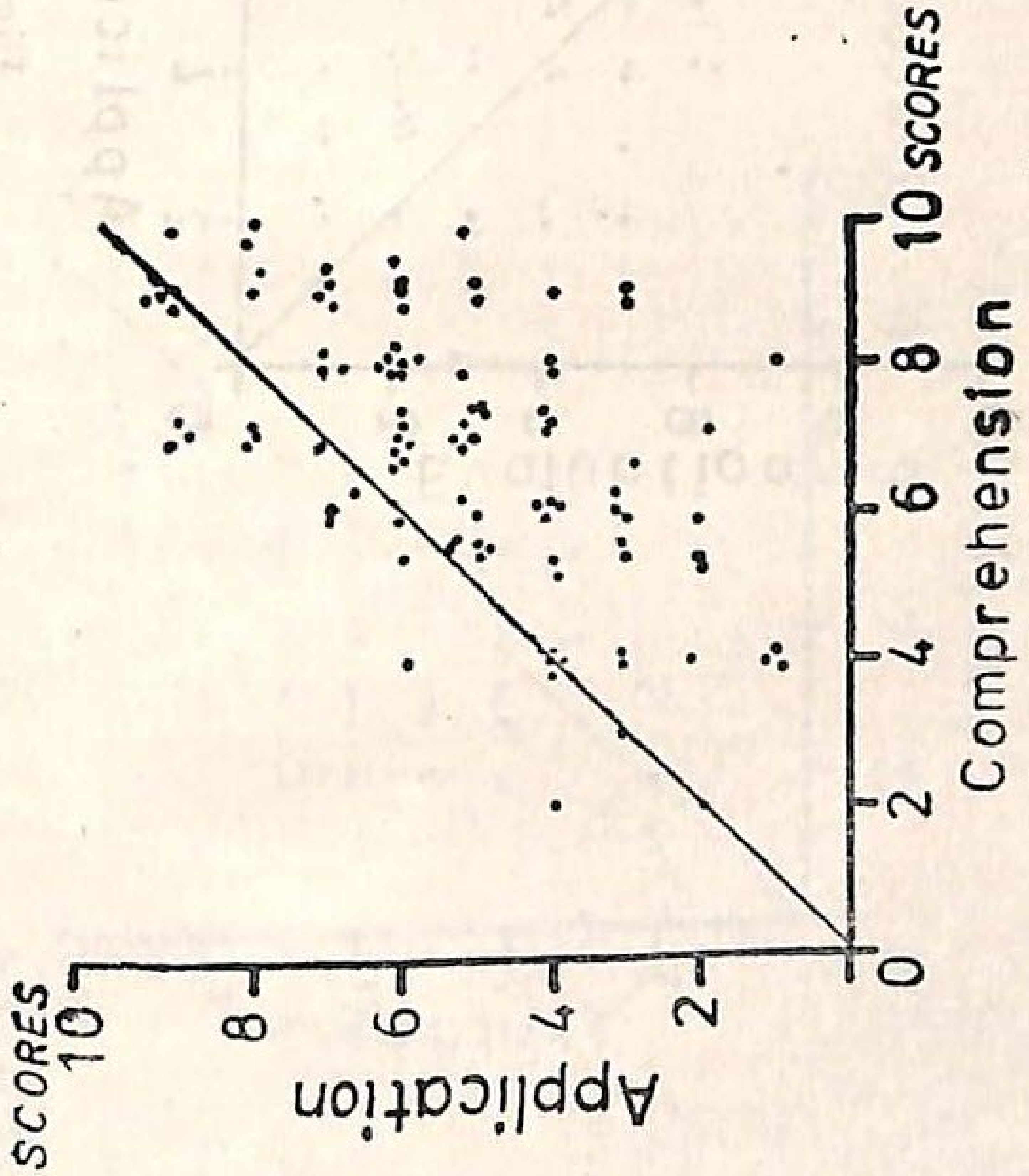


Fig. 7F

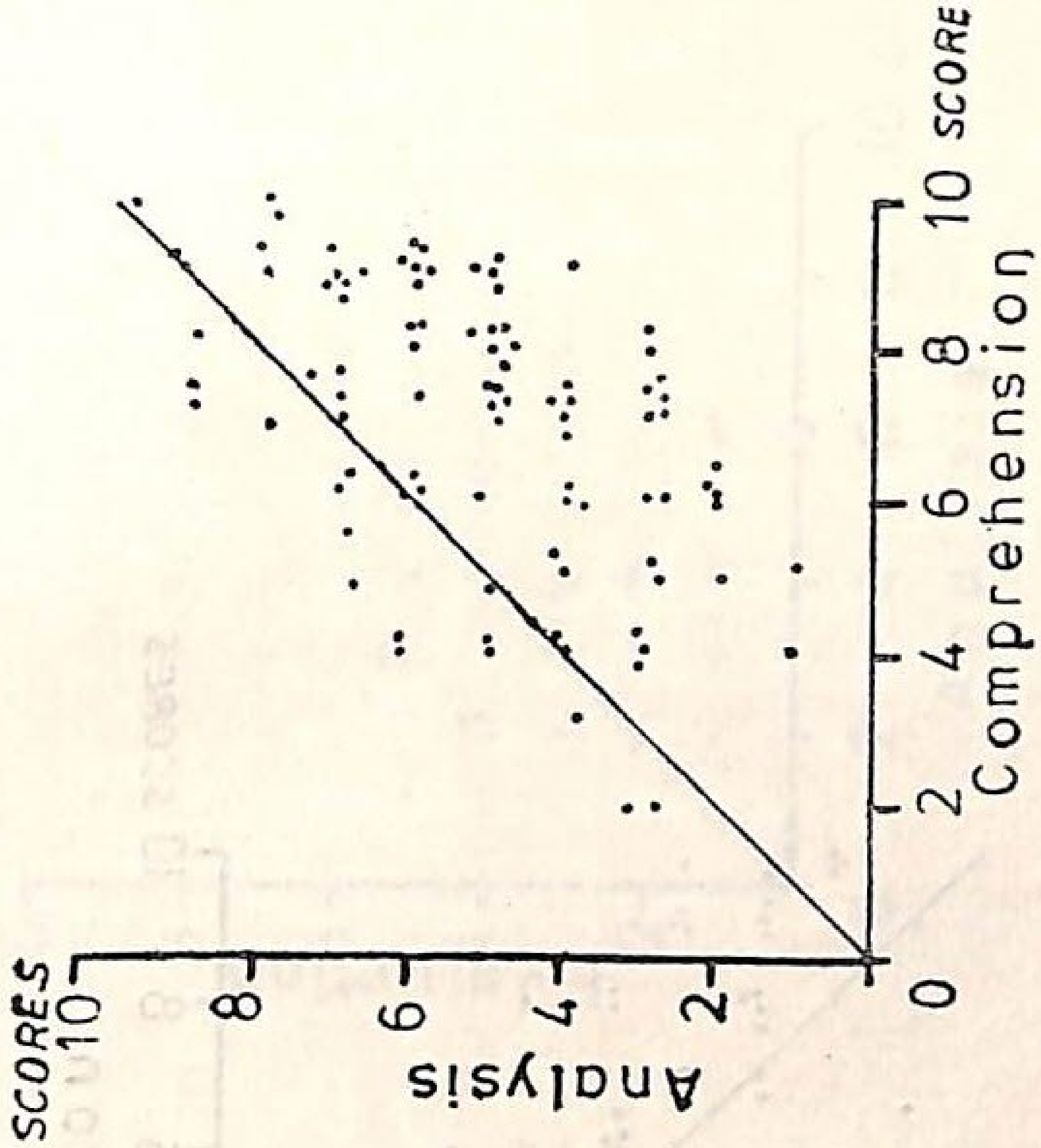


Fig. 7G

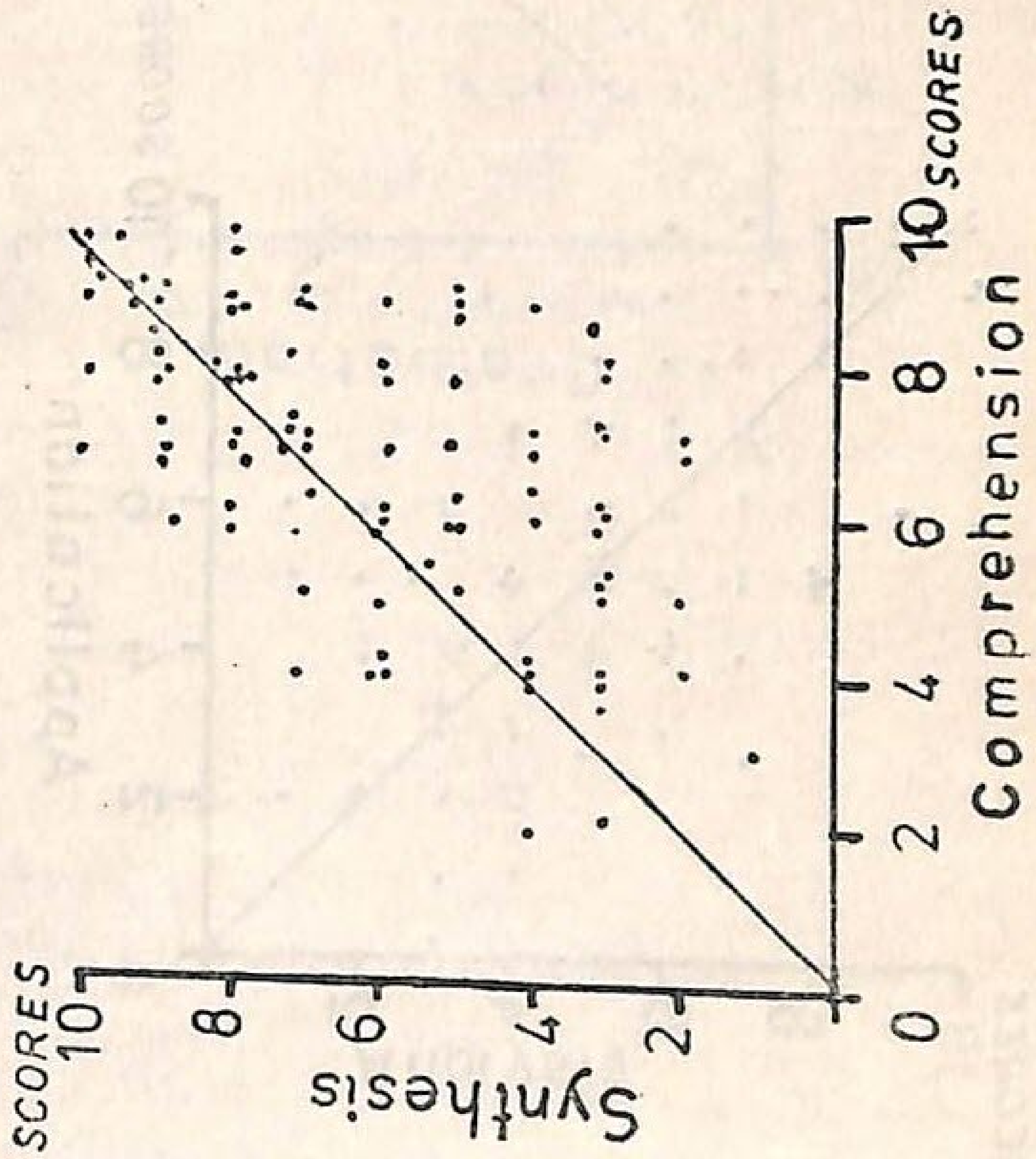


Fig. 7H

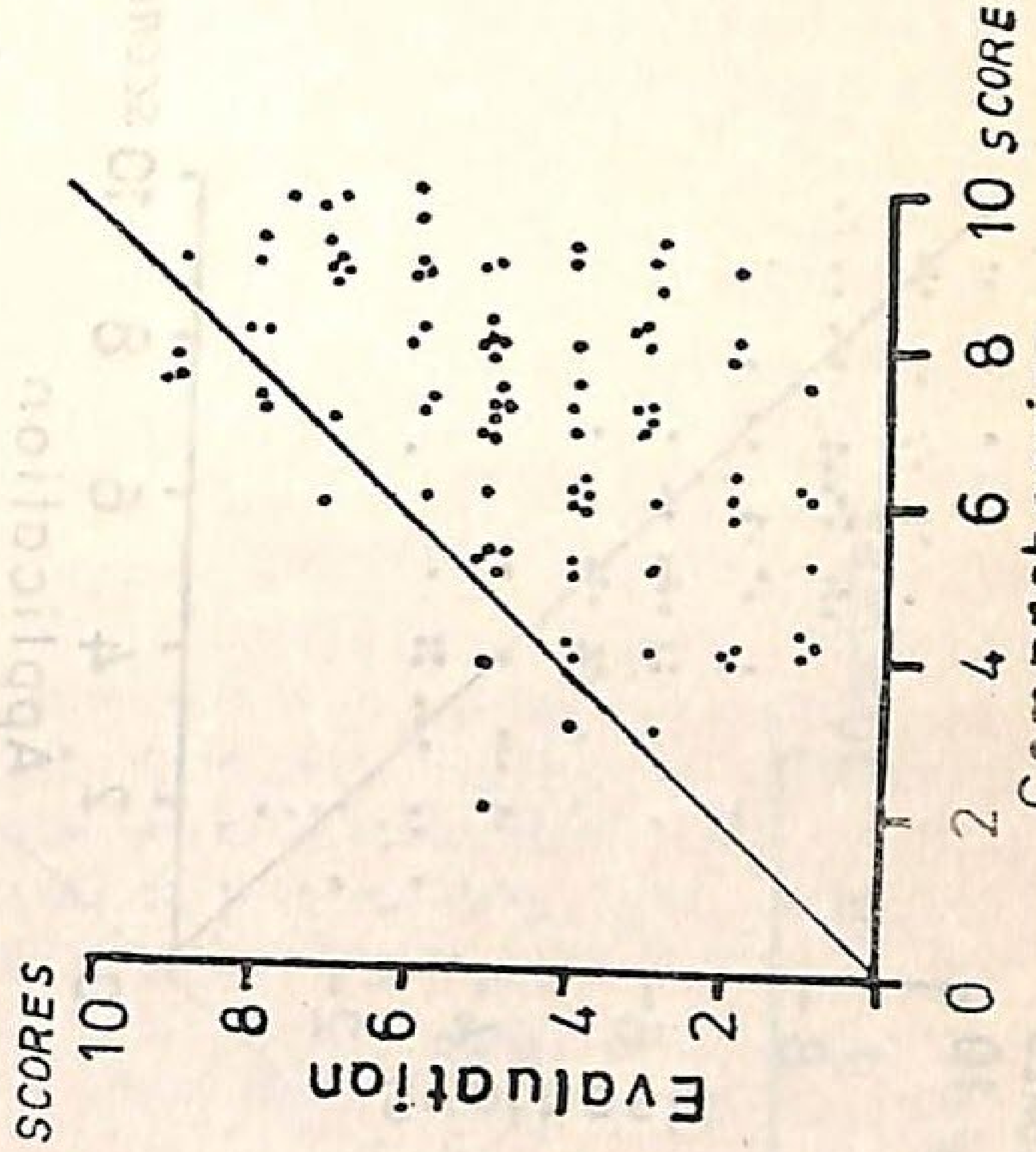


Fig. 7I

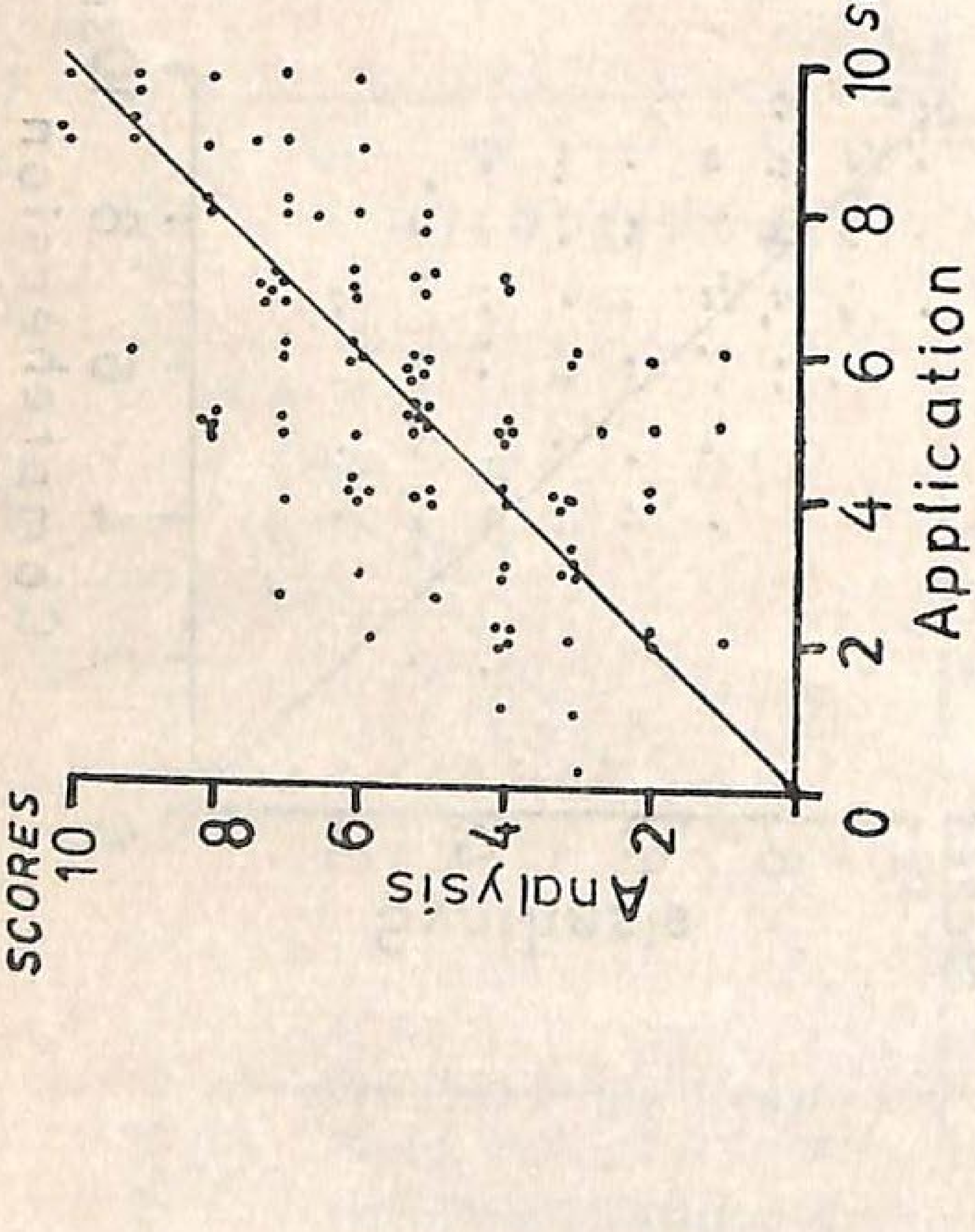


Fig. 7J

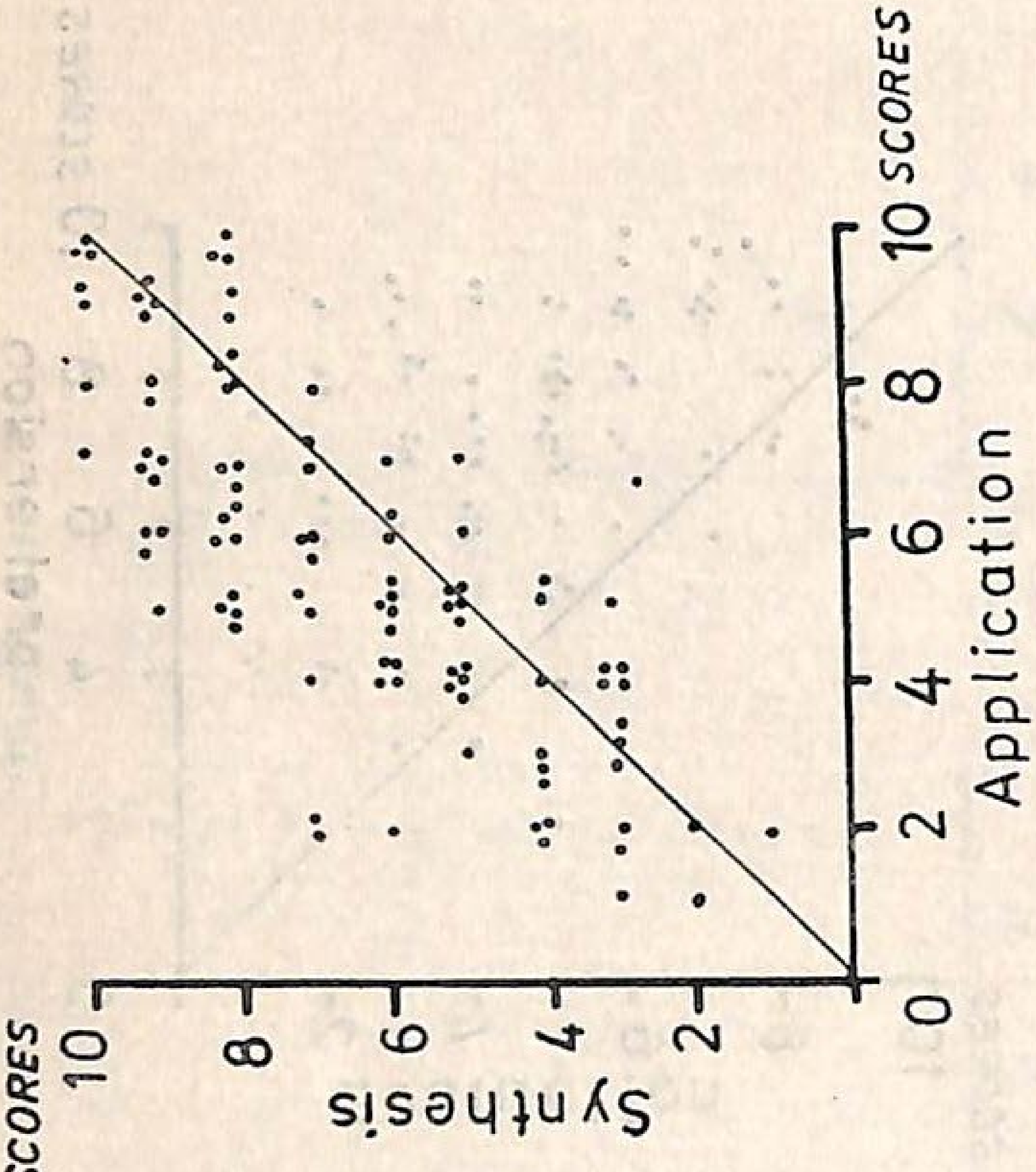


Fig. 7K

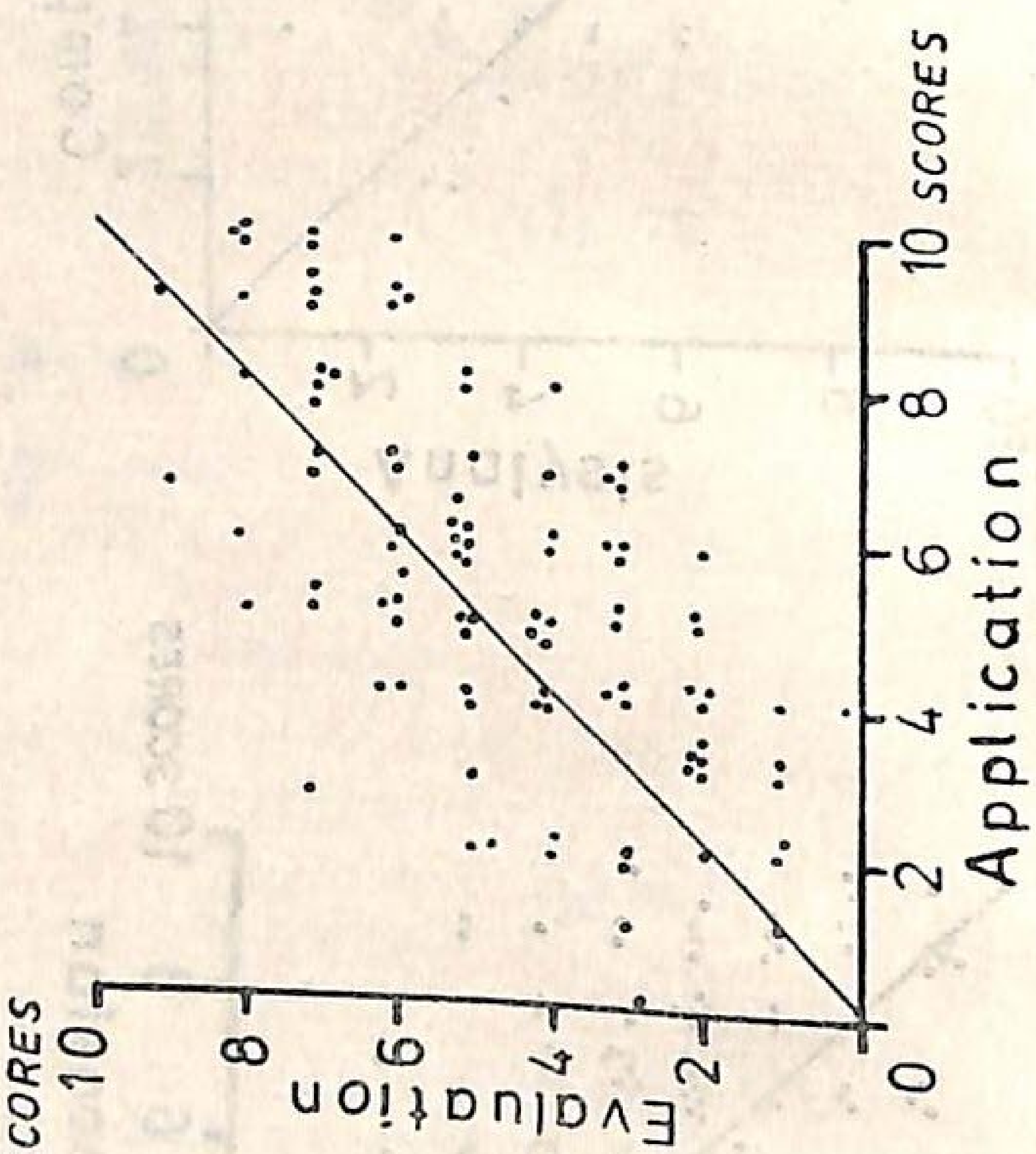


Fig. 7L

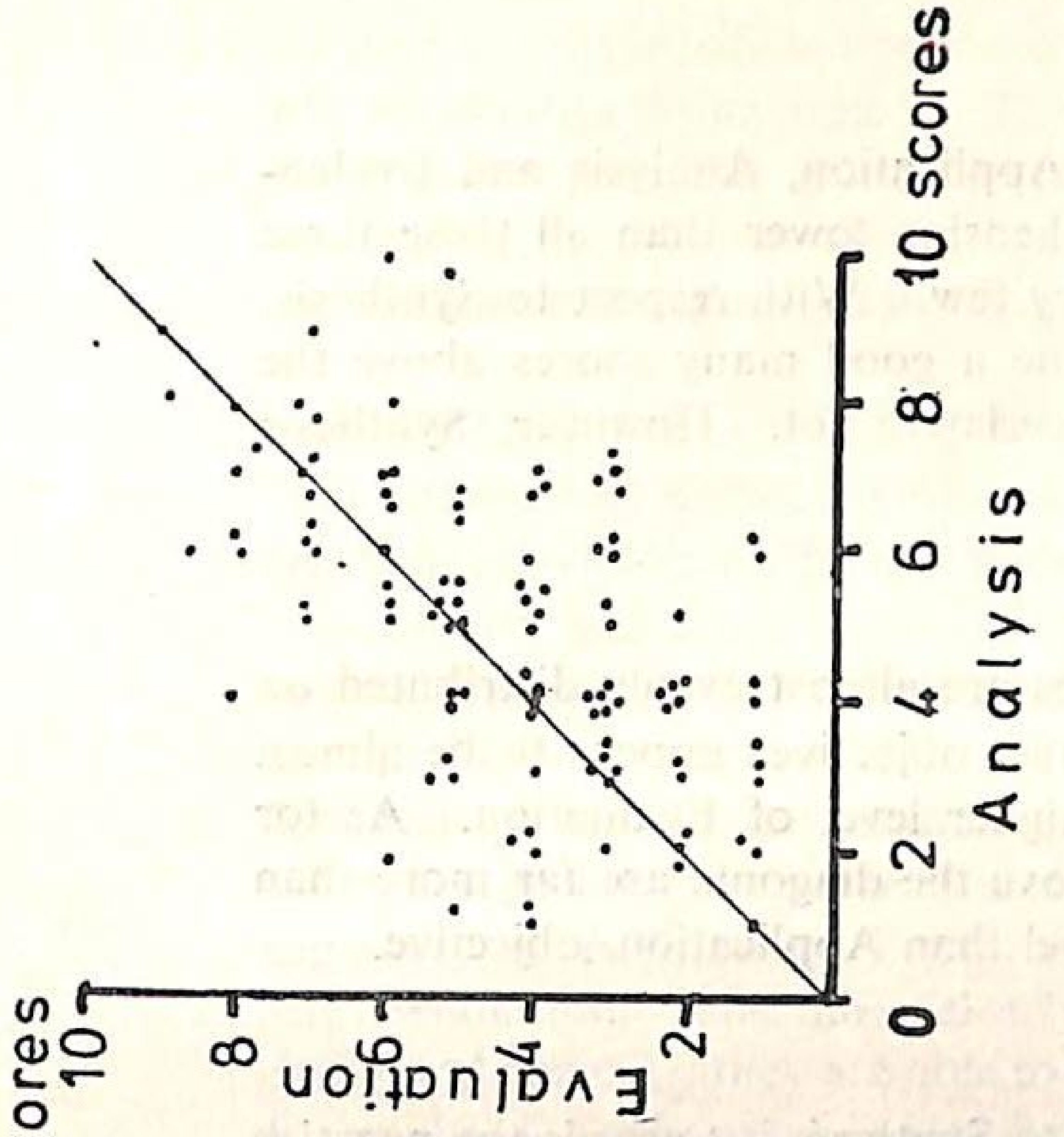


Fig. 7N

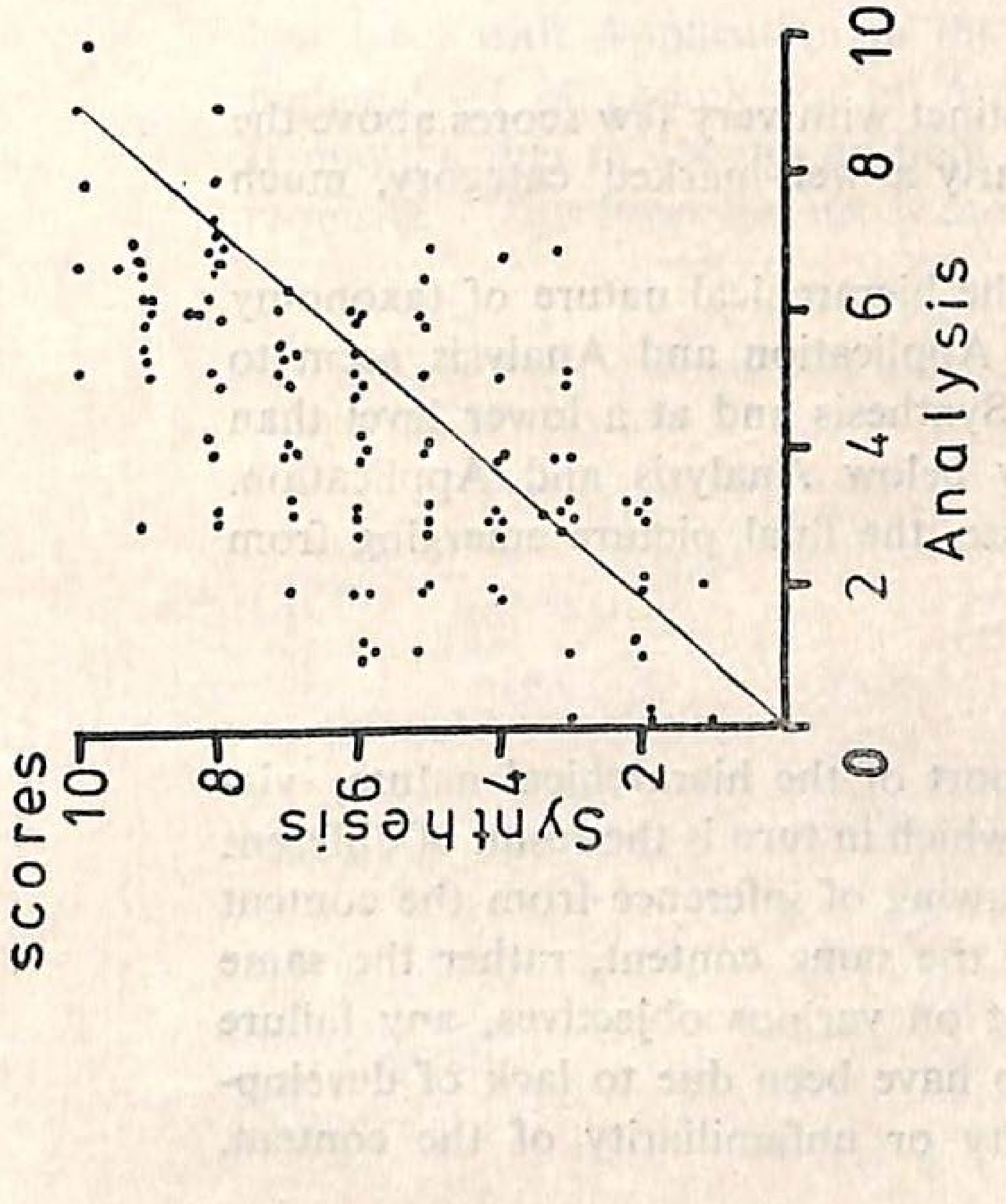


Fig. 7M

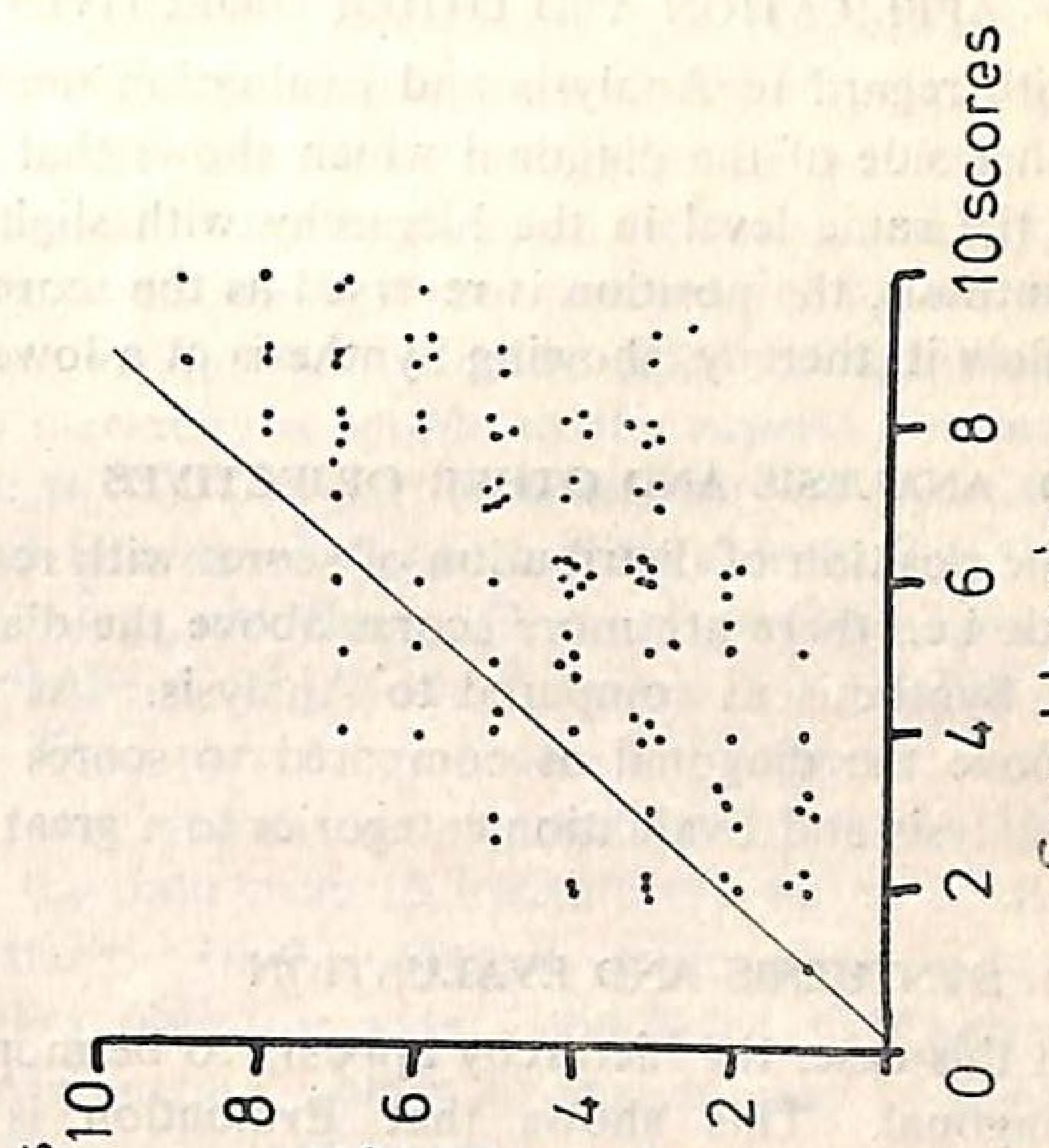


Fig. 7O

the position is somewhat similiar as with Application and Analysis categories. With respect to Evaluation, the distribution is almost triangular which indicates a marked distance of evaluation category at the top of hierarchy.

(ii) COMPREHENSION AND OTHER OBJECTIVES

The position of Comprehension, with respect to Application, Analysis and Evaluation, indicates marked hierarchy putting Comprehension lower than all these three objectives as the scores above the diagonal are very few. With respect to Synthesis, however, the position is different as there are quite a good many scores above the diagonal which shows that the two categories overlap a lot. However, Synthesis is slightly higher in hierarchy.

(iii) APPLICATION AND OTHER OBJECTIVES

With regard to Analysis and Evaluation the scores are almost evenly distributed on either side of the diagonal which shows that the two objectives appear to be almost at the same level in the hierarchy with slightly higher level of Evaluation. As for Synthesis, the position is reversed as the scores above the diagonal are far more than below it, thereby, showing Synthesis at a lower level than Application, objective.

(iv) ANALYSIS AND OTHER OBJECTIVES

The position of distribution of scores with respect to Synthesis is towards the negative side i.e., there are more scores above the diagonal which indicates the lower position of Synthesis as compared to Analysis. As for Evaluation, the scores although less above the diagonal as compared to scores below the diagonal there is overlap of Analysis and Evaluation categories to a great extent.

(v) SYNTHESIS AND EVALUATION

In this case, the hierarchy appears to be more distinct with very few scores above the diagonal. This shows that Evaluation is clearly a well-marked category, much higher in hierarchy than Synthesis.

From the above observations, it is evident that the hierarchical nature of taxonomy is clear in the case of first and last objective. Application and Analysis seem to merge and both function at a higher level than Synthesis and at a lower level than Evaluation. Comprehension also falls distinctly below Analysis and Application. Even Synthesis has slight edge over it. Therefore, the final picture emerging from this analysis would be K→C→S→AP/AN→E.

8.2.4 LOGIC OF THE TAXONOMIC TEST

Another point that can be stressed here in support of the hierarchical nature, vis-a-vis the significance of difference in achievement which in turn is the result of different abilities implied by different objectives, is the drawing of inference from the content validity of the test used to get evidence. Since the same content, rather the same concept, is used in testing students' achievement on various objectives, any failure to attempt an item on an objective is deemed to have been due to lack of development of those abilities and not due to difficulty or unfamiliarity of the content.

Failure to solve an item on Application implies one's failure at not having mastered the abilities of previous levels (K and C in this case) needed for solving the same. When different content is used to test on different objectives, the failure to attempt an item can be attributed to the complexity of the content and not solely to the lack of the abilities being tested. Therefore, nature of hierarchy can be inferred from the stimulus provided in the item, as long as the test constructor ensures that content for testing the various abilities along the process continuum remains more or less the same as is the position in the present case.

8.2.5 INFERENTIAL EVIDENCE FROM EXPERTS' JUDGMENT

The hierarchical nature could also be inferred from the expert analysis of the items for their classification in the respective categories. It was not uncommon to find that experts had more clearly categorised items on Knowledge and Evaluation, the two extreme categories, while Synthesis items were degraded in classifying them into Comprehension many a time. These items were either categorised as items of Synthesis or of Comprehension and sometimes as Application items and rarely in other categories. To some extent it again throws light on hierarchical nature and especially of position of Comprehension Vs Synthesis, besides that of Knowledge and Evaluation. The more clearly the hierarchy is visible to the experts the more easily and correctly they are able to place an item in a particular category of objectives. From the analysis of empirical data and inferential evidence from rater's classification and frequency distribution, two things are clear. One, hierarchy is observable clearly from Knowledge to Application objectives followed by Evaluation category at the top of the hierarchy. Two, present position of 'Synthesis' in the ladder of hierarchy is not supported by evidence as it only approximates the level of 'Comprehension'. As for 'Analysis' the data seem to indicate almost an equivalent level with Application in the hierarchy. In fact there is evidence to indicate higher level of complexity of Application objective when compared to Analysis. It may be that in solving an item on 'Application' ability to analyse may be a prerequisite. This however, needs more evidence to corroborate.

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ANNEXURE

(a)

MATRICES SHOWING DIFFERENCES IN MEANS AND t VALUES.
SCHOOL-WISE AND CLASS-WISE

1.1 N=76 df=75 0.05=1.99 0.01=2.640

Objectives		**K**	**C**	**AP**	**AN**	**N**	**E**
K	D.M.	—	1.54	2.90	2.49	1.89	3.58
	t		3.74	7.39	6.45	4.40	9.88
C	D.M.			1.35	0.95	0.36	2.04
	t			3.74	2.67	0.88	6.19
AP	D.M.				2.40	−0.99	0.69
	t				1.23	2.60	2.24
AN	D.M.					−0.59	1.09
	t					1.57	3.68
S	D.M.						1.68
	t						4.76
E	D.M.						—
	t						—

1.2 N=73 df=72 0.05=2.00 0.01=2.625

Objectives		**K**	**C**	**AP**	**AN**	**N**	**E**
K	D.M.	—	1.75	3.15	3.38	2.20	3.64
	t	—	4.38	8.26	9.39	5.47	10.11
C	D.M.			1.40	1.63	0.45	1.89
	t			3.59	4.42	1.11	5.13
AP	D.M.				0.23	0.95	0.49
	t				0.67	2.41	1.42
AN	D.M.					−1.18	0.26
	t					3.17	0.80
S	D.M.						1.44
	t						3.87
E	D.M.						—
	t						—

1.3 N=18 df=17 0.05=2.11 0.01=2.900

Objectives		K	C	AP	AN	N	E
K	D.M.	—	0.28	1.39	1.89	0.22	3.28
	t	—	0.33	1.56	2.29	0.24	3.87
C	D.M.			1.67	2.17	0.50	3.56
	t			1.96	2.77	0.57	4.43
AP	D.M.				0.50	1.17	1.89
	t				0.60	1.25	2.20
AN	D.M.					1.67	1.39
	t					1.91	1.76
S	D.M.						3.06
	t						3.44
E	D.M.						—
	t						—

(b)

2.1 N=32 df=31 0.05=2.04 0.01=2.75

Objectives		K	C	AP	AN	S	E
K	D.M.	—	2.34	2.65	1.87	0.44	3.31
	t	—	4.38	4.85	3.54	0.75	5.69
C	D.M.			0.31	−0.47	−1.90	0.97
	t			0.56	0.86	3.21	1.63
AP	D.M.				−0.78	−2.21	0.66
	t				1.41	3.66	1.08
AN	D.M.					−1.43	1.44
	t					2.44	2.44
S	D.M.						2.87
	t						4.51
E	D.M.						—
	t						—

2.2 N=28 df=27 0.05=2.05 0.01=2.77

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.79	3.54	3.86	1.18	4.46
	t	—	4.05	7.80	7.60	2.62	9.59
C	D.M.			1.75	2.03	−0.61	2.67
	t			3.51	3.74	1.22	5.26
AP	D.M.				0.28	−2.36	0.92
	t				0.52	4.65	1.78
AN	D.M.					2.64	0.64
	t					4.79	1.14
S	D.M.						3.28
	t						6.34
E	D.M.						—
	t						—

2.3 N=26 df=25 0.05=2.06 0.01=2.99

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.34	2.42	2.69	0.88	4.07
	t	—	2.88	4.69	5.90	2.29	7.28
C	D.M.			1.08	1.35	−0.46	2.73
	t			1.89	2.61	1.01	4.47
AP	D.M.				0.27	−1.54	1.65
	t				0.48	3.04	2.55
AN	D.M.					−1.81	1.38
	t					4.07	2.30
S	D.M.						3.19
	t						5.80
E	D.M.						—
	t						—

(c)

3.1 N=34 df=33 0.05=2.03 0.01=2.72

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.21	2.94	2.09	1.85	2.88
	t	—	2.51	7.29	4.96	3.90	7.44
C	D.M.			1.73	0.88	0.64	1.67
	t			4.08	2.00	1.31	4.08
AP	D.M.				−0.85	−1.09	−0.06
	t				2.40	2.60	1.86
AN	D.M.					−0.24	0.79
	t					0.54	2.35
S	D.M.						1.03
	t						2.55
E	D.M.						—
	t						—

3.2 N=36 df=35 0.05=2.03 0.01=2.72

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.21	2.94	2.09	1.85	2.88
	t	—	3.42	6.12	4.94	2.62	4.54
C	D.M.			1.73	0.88	0.64	1.67
	t			2.73	1.46	0.51	1.20
AP	D.M.				−0.85	−1.09	−0.06
	t				1.36	2.96	1.46
AN	D.M.					−0.24	0.79
	t					1.83	1.82
S	D.M.						1.03
	t						1.59
E	D.M.						—
	t						—

3.3 N=41 df=40 0.05=2.02 0.01=2.71

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.52	3.76	3.84	3.84	4.37
	t	—	2.49	6.29	7.06	6.51	7.31
C	D.M.			2.24	2.32	2.32	2.85
	t			3.84	4.40	4.03	4.89
AP	D.M.				0.08	0.08	0.61
	t				0.14	0.13	1.06
AN	D.M.					0.00	0.53
	t					0.00	1.04
S	D.M.						0.53
	t						0.95
E	D.M.						—
	t						—

(d)

4.1 N=42 df=41 0.05=2.02 0.01=2.71

Objectives		K	C	AP	AN	S	E
K	D.M.	—	0.85	2.90	1.95	1.62	2.56
	t	—	2.10	7.39	4.26	3.52	5.65
C	D.M.			2.05	1.10	0.77	1.72
	t			6.20	2.62	1.78	4.21
AP	D.M.				−0.95	−1.28	−0.33
	t				2.65	3.56	0.94
AN	D.M.					−0.33	0.62
	t					0.77	1.45
S	D.M.						0.95
	t						2.23
E	D.M.						—
	t						—

4.2 N=27 df=26 0.05=2.06 0.01=2.78

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.60	3.52	3.57	1.86	3.12
	t	—	2.88	5.60	6.12	2.84	4.60
C	D.M.			1.92	1.97	0.26	1.52
	t			3.31	3.70	0.43	4.40
AP	D.M.				0.05	−1.66	−0.40
	t				0.06	2.46	0.56
AN	D.M.					−1.71	−0.45
	t					2.69	0.67
S	D.M.						1.26
	t						1.75
E	D.M.						—
	t						—

4.3		N=26	df=25		0.05=2.06		0.01=2.79
Objectives		**K**	**C**	**AP**	**AN**	**S**	**E**
K	D.M.	—	2.08	3.00	2.73	1.19	3.43
	t	—	3.01	3.97	3.73	1.72	4.81
C	D.M.			0.92	0.65	−0.89	1.35
	t			1.27	0.94	1.34	1.98
AP	D.M.				−0.27	−1.81	0.43
	t				0.35	2.48	0.57
AN	D.M.					−1.54	0.70
	t					2.19	0.96
S	D.M.						2.24
	t						3.27
E	D.M.						—
	t						—

(e)

5.1		N=29	df=28		0.05=2.05		0.01=2.76
Objectives		**K**	**C**	**AP**	**AN**	**S**	**E**
K	D.M.	—	1·17	2.51	1.86	0.07	2.79
	t	—	1.82	4.49	2.79	0.11	5.05
C	D.M.			1.34	0.69	−1.10	1.62
	t			2.46	1.05	1.76	3.02
AP	D.M.				−0.65	−2.64	0.28
	t				1.15	4.59	0.64
AN	D.M.					−1.79	0.93
	t					2.78	1.65
S	D.M.						2.72
	t						5.19
E	D.M.						—
	t						—

5.2		N=30	df=29		0.05=2.04		0.01=2.76
Objectives		**K**	**C**	**AP**	**AN**	**S**	**E**
K	D.M.	—	2.37	3.57	3.47	2.77	4.80
	t	—	4.63	6.88	6.65	4.76	10.56
C	D.M.			1.20	1.10	0.40	2.41
	t			2.17	1.98	0.65	4.93
AP	D.M.				−0.10	−0.80	1.23
	t				0.18	1.29	2.46
AN	D.M.					−0.70	1.33
	t					1.13	2.64
S	D.M.						2.03
	t						3.59
E	D.M.						—
	t						—

5.3 N=48 df=47 0.05=2.02 0.01=2.69

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.48	3.06	3.10	1.79	3.98
	t	—	3.19	6.77	6.77	3.93	10.25
C	D.M.			1.58	1.62	0.31	2.50
	t			3.39	3.44	0.66	6.16
AP	D.M.				0.04	−1.27	0.92
	t				0.09	2.77	2.33
AN	D.M.					−1.31	0.88
	t					2.82	2.19
S	D.M.						2.19
	t						5.52
E	D.M.						—
	t						—

(f)

6.1 N=36 df=35 0.05=2.03 0.01=2.72

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.63	2.52	2.63	1.19	3.66
	t	—	2.76	4.35	4.47	2.02	6.73
C	D.M.			0.89	0.00	−0.44	2.03
	t			1.53	1.70	0.75	3.34
AP	D.M.				0.11	−1.33	1.14
	t				0.19	2.30	2.15
AN	D.M.					−1.44	1.03
	t					2.45	1.90
S	D.M.						2.47
	t						4.56
E	D.M.						—
	t						—

6.2 N=33 df=32 0.05=2.04 0.01=2.75

Objectives		K	C	AP	AN	S	E
K	D.M.	—	1.33	2.18	2.60	0.57	3.60
	t	—	2.67	3.97	5.00	1.12	7.22
C	D.M.			0.35	1.27	−0.76	2.27
	t			1.44	2.27	1.36	4.20
AP	D.M.				0.42	1.61	1.42
	t				0.70	2.67	2.42
AN	D.M.					−2.03	1.00
	t					3.52	1.78
S	D.M.						3.03
	t						5.44
E	D.M.						—
	t						—

6.3		N=18	df=17	0.05=2.11		0.01=2.90	
Objectives		**K**	**C**	**AP**	**AN**	**S**	**E**
K	D.M.	—	1.34	2.61	2.34	0.89	3.50
	t	—	2.08	4.26	3.58	1.47	6.04
C	D.M.			1.27	1.00	−0.45	2.16
	t			1.66	1.25	0.58	2.90
AP	D.M.				−0.27	−1.72	0.89
	t				0.36	2.32	1.23
AN	D.M.					−1.45	1.16
	t					1.87	1.55
S	D.M.						2.61
	t						3.65
E	D.M.						—
	t						—

(g)

7.1		N=43	df=42	0.05=2.02		0.01=2.71	
Objectives		**K**	**C**	**AP**	**AN**	**S**	**E**
K	D.M.	—	2.07	2.74	3.12	1.90	3.23
	t	—	4.76	4.36	7.45	4.15	7.74
C	D.M.			0.67	1.05	−0.17	1.16
	t			1.21	3.50	0.46	3.90
AP	D.M.				0.38	0.58	0.49
	t				0.68	1.45	0.90
AN	D.M.					−1.22	0.11
	t					3.62	0.42
S	D.M.						1.33
	t						3.98
E	D.M.						—
	t						—

7.2		N=42	df=41	0.05=2.02		0.01=2.71	
Objectives		**K**	**C**	**AP**	**AN**	**S**	**E**
K	D.M.	—	2.59	3.31	3.31	2.35	3.57
	t	—	5.22	7.04	6.19	4.79	7.43
C	D.M.			0.72	9.72	−0.24	0.98
	t			1.84	1.54	0.57	2.45
AP	D.M.				0.00	−0.96	0.86
	t				0.00	2.49	0.71
AN	D.M.					−0.96	0.26
	t					2.07	0.59
S	D.M.						1.22
	t						3.07
E	D.M.						—
	t						—

7.3 N=8 df=7 0.05=2.36 0.01=3.50

Objectives		K	C	AP	AN	S	E
K	D.M.	—	0.87	2.00	2.62	0.62	3.26
	t	—	0.84	1.26	2.40	0.50	2.88
C	D.M.			1.13	1.75	—0.25	2.38
	t			0.79	2.05	0.24	2.65
AP	D.M.				0.62	—1.38	1.25
	t				0.43	0.87	0.84
AN	D.M.					—2.00	0.63
	t					1.81	0.65
S	D.M.						2.63
	t						2.31
E	D.M.						—
	t						—

(h)

8.1 N=29 df=28 0.05=2.05 0.01=2.76

Objectives		K	C	AP	AN	S	E
K	D.M.	—	0.17	1.00	0.86	1.04	0.93
	t	—	0.42	2.58	2.22	2.62	2.26
C	D.M.			0.83	0.69	0.87	0.76
	t			2.90	2.40	2.92	2.38
AP	D.M.				—0.14	0.04	—0.07
	t				0.55	0.13	0.24
AN	D.M.					0.18	0.07
	t					0.66	0.24
S	D.M.						0.11
	t						0.35
E	D.M.						—
	t						—

8.2 N=22 df=21 0.05=2.08 0.01=2.83

Objectives		K	C	AP	AN	S	E
K	D.M.	—	3.14	3.46	3.18	3.23	4.14
	t	—	5.06	6.23	5.61	5.32	7.16
C	D.M.			0.32	0.04	0.09	1.00
	t			0.61	0.08	0.16	1.82
AP	D.M.				—0.28	—0.23	0.68
	t				0.59	0.45	1.43
AN	D.M.					0.05	0.96
	t					0.87	1.94
S	D.M.						0.91
	t						1.70
E	D.M.						—
	t						—

8.3 N=15 df=14 0.05=2.14 0.01=2.98

Objectives		**K**	**C**	**AP**	**AN**	**S**	**E**
K	D.M.	—	2.80	4.53	3.47	3.00	5.40
	t	—	4.26	4.99	6.57	4.30	7.25
C	D.M.			1.73	1.86	0.20	2.60
	t			2.17	3.32	0.37	4.30
AP	D.M.				0.13	−1.53	0.87
	t				0.16	1.85	1.00
AN	D.M.					−1.66	0.74
	t					2.73	1.11
S	D.M.						2.40
	t						3.70
E	D.M.						—
	t						—

9

9.0 VALIDATING THE CUMULATIVENESS OF THE HIERARCHY

For testing the cumulative nature of the taxonomy the following null hypothesis was formulated :

TESTING OF HYPOTHESIS—2

H : 2 Different objectives categorised in the taxonomy do not form a cumulative hierarchy but are independent of each other.

To test this hypothesis, following techniques were employed :

9.1 Study of the shape of the curves of frequency distribution of scores on different objectives, for each class.
9.2 Analysis of frequency distributions of scores in terms of high, middle and low scores by using chi-square technique, for the three classes.
9.3 Relationship of students' performance on different objectives.
9.4 Guttman's Radex technique of Simplical Structure.
9.5 Analysis of objective-wise cumulative scores.
9.6 Factor analysis of inter-objective correlation matrix.
9.7 McQuitty's Syndrome Analysis technique of classification.

9.1 SHAPE OF CURVES OF FREQUENCY DISTRIBUTION

Shape of the curves are shown in figures 4, 5 and 6 for classes IX, X and XI respectively. These curves were examined from two angles, the skewness and the density of scores at the two ends. Observations were made with respect to the six graphs for each class. With respect to class IX there is a clear indication of the positive skewness which goes on increasing as we move from 'Knowledge' to 'Evaluation' category. Whereas in Knowledge the curve is slightly skewed negatively, in 'Evaluation' it is highly skewed positively. This shows clustering of frequencies on the lower end which supports the contention that higher level mental processes get more and more involved as we proceed from K to E and the achievement level declines in the same order. As for the density of scores similar trend is there but for synthesis category which appears to be misplaced. Greater density at the lower end in application as compared to analysis is also intriguing.

Position is not very different for class X except that curves of Application and Analysis as also the densities at the lower end are almost the same which shows merger of the two categories.

In class XI the curve is negatively skewed for Knowledge objective and there is a gradual shift from the negative to the positive skewness as we move from Knowledge to Evaluation. Position of Synthesis and Analysis does not fit in cumulative hierarchy. Density of scores, however, at the lower end is not that sharp as observable in classes IX and X. It appears that due to higher level of achievement in class XI, therefore few students at the lower end of the continuum as evident from comparatively more platykurtic curve. The study of the curves, therefore, rejects the null hypothesis of no cumulative hierarchy with respect to K, C, AP and even E to a large extent but not in case of Analysis and Synthesis.

9.2 FREQUENCY DISTRIBUTION OF HIGH AND LOW RANGES OF SCORES

Dave (1976) made an attempt to deduce from the taxonomical assumptions regarding cumulative hierarchy that :

> "if a large, randomly selected normal sample is given test on Knowledge, Understanding and Application, the frequency distribution of the same sample will be different from all the three categories. He predicted that frequency of students making correct responses in the higher attainment range in knowledge will decrease for the same higher range in 'Understanding' and will decrease still more in 'Application'. In other words whatever frequency distribution for a particular category, one may start with the distribution for the higher or the lower category would be skewed as per decrease or increase in the complexity of the category for which measurement is made."

From the graphic representation it is noticed that there is clearly observable trend in the density of scores. In the lower range of marks (0–3) there is low density on lower level objectives and high on higher level objectives. On the other hand with respect to higher range of marks (7–10) it is high on knowledge and low on Evaluation. Class-wise consolidated position of scores with respect to six objectives is given in table 23, while tables 24, 25 and 26 show the frequencies for each school over each objective for classes IX, X and XI as distributed over the low, middle and high ranges of marks.

Table 23

OVERALL CLASS-WISE SCORES IN THREE RANGES FOR DIFFERENT OBJECTIVES

Categories	Low Range 0-3 marks				Middle Range 4-6 marks				High Range 7-10 marks			
Classes	IX	X	XI	Total	IX	X	XI	Total	IX	X	XI	Total
Objectives												
K	122	043	017	182	119	113	048	280	080	115	135	330
C	200	134	039	373	091	117	076	284	040	039	085	164
AP	256	176	085	518	047	082	066	195	017	017	048	164
AN	245	197	082	524	054	082	060	196	022	012	040	074
S	197	138	056	391	077	098	057	232	047	055	087	189
E	276	223	114	613	040	066	066	172	013	012	020	045

From Table 23 the scores under the low group (consolidated) go on increasing from Knowledge (182) to Evaluation (613). The position is just the reverse in case of high range of scores where it is the highest (330) in Knowledge and lowest (45) in Evaluation. In the middle range the position is also similar but not as clear as in the two extreme categories. However, it is the 'Synthesis' category only in all the three ranges, that is out of place and disturbs the trend indicated above. Thus taxonomic assumption about cumulative hierarchy is supported by these data of frequency distribution in low and high ranges of scores (IX, X and XI together).

Class-wise analysis also reveals similar trend. In table 23, class IX frequency distributions go on increasing in the lower range of marks (0–3) i.e., more and more students are getting less and less marks. As we proceed from knowledge (f=122, class IX) to evaluation (f=276) there is gradual increase. On the other hand in the high range of marks (7–10) more students get higher marks on lower objectives like 'knowledge' (f=80) and this goes on decreasing with the increase in hierarchical level of objectives till we reach 'evaluation' category where lowest (f=13) frequencies are there. Thus shift in clustering of frequencies from the lower to the upper end of the continuum making the distribution more and more positively skewed, indicates the increasing complexity and cumulative hierarchy of the taxonomy. Category of Synthesis is, however, intriguing and seems to be out of place. Position of Analysis category also does not appear to be in order and it seems to fall in line with the Application objective.

Table 24, 25 and 26 which pertain to school-wise data were examined further. It shows that except for the inconsistent behaviour of the 'Synthesis' category and to a great extent similar behaviour of 'Analysis', the position in respect of all the eight schools in each of the three classes is in no way different. Thus the evidence that accrues from the analysis of high and low scores on different objectives corroborates the evidence gathered from the study of shape of frequency distributions. The null hypothesis when restricted to K, C, AP and E, can be said to have been rejected, thereby confirming the cumulative hierarchy in case of these four objectives.

Table 24

SCHOOL-WISE FREQUENCY DISTRIBUTION OF SCORES IN TERMS OF HIGH AND LOW RANGE

CLASS—IX N=321

Low Range (0-3 marks)

Objective	1	2	3	4	5	6	7	8	Total
K	27	02	14	21	12	06	17	23	122*
C	43	12	23	27	19	14	35	27	200
AP	62	15	32	41	25	13	41	28	256
AN	57	09	30	34	23	22	41	29	245
S	51	07	25	33	11	10	31	29	197
E	67	18	33	38	25	26	41	28	276

Middle Range (4-6)

Objective	1	2	3	4	5	6	7	8	Total
K	28	11	18	17	11	11	18	05	119
C	25	15	09	15	07	11	07	02	091
AP	12	12	02	01	04	15	00	01	047
AN	18	22	04	07	03	08	02	00	054
S	17	08	08	07	11	15	11	00	077
E	08	12	01	03	04	09	02	01	040
High Range (7-10)									
K	21	19	02	04	06	19	08	01	080*
C	08	15	02	00	03	11	01	00	040
AP	03	05	00	00	00	08	01	00	017
AN	01	11	00	01	03	06	00	00	022
S	08	17	01	02	07	11	01	00	047
E	09	02	00	01	00	01	00	00	013

Table 25

SCHOOL-WISE FREQUENCY DISTRIBUTION OF SCORES IN TERMS OF HIGH AND LOW

CLASS—X

N=291

Low Range (0-3)

School Object	1	2	3	4	5	6	7	8	Total
K	13	00	13	05	01	01	06	04	043
C	31	06	27	08	17	09	22	14	134
AP	47	51	32	18	20	17	31	16	176
AN	54	14	29	17	19	19	27	18	197
S	41	03	24	09	19	05	20	17	138
E	52	18	30	16	27	22	30	18	223
Middle Range (4-6)									
K	33	07	16	14	16	18	20	09	133
C	29	17	07	15	09	15	18	07	117
AP	22	15	03	07	09	10	10	06	082
AN	18	12	07	10	10	09	12	04	082
S	18	13	07	13	07	15	20	05	098
E	19	09	04	07	03	08	12	04	066

High Range (7-10)

School Object	1	2	3	4	5	6	7	8	Total
K	27	21	07	08	13	14	16	09	115
C	12	05	02	04	04	09	12	01	039
AP	04	02	01	02	01	06	01	00	017
AN	01	02	00	00	01	05	03	00	012
S	14	12	05	05	04	13	02	00	055
E	02	01	02	04	00	03	00	00	012

Table 26

SCHOOL-WISE FREQUENCY DISTRIBUTION OF SCORES IN TERMS OF HIGH AND LOW

CLASS—XI N=200

Low Range (0-3)

School Object	1	2	3	4	5	6	7	8	Total
K	01	00	06	02	06	00	01	01	017
C	01	01	12	08	14	01	00	02	039
AP	04	03	25	14	25	03	02	10	086
AN	03	05	26	11	26	03	01	07	082
S	03	00	25	06	17	02	01	02	056
E	07	10	28	14	38	05	01	11	114

Middle Range (4-6)

K	07	03	09	08	17	02	00	02	048
C	07	07	13	10	21	04	02	12	076
AP	07	13	12	06	19	05	01	03	066
AN	11	10	12	10	18	06	03	08	060
S	04	03	11	10	18	00	00	11	057
E	09	10	10	09	09	10	05	04	066

High Range (7-10)

K	10	23	26	16	25	16	07	12	135
C	10	18	16	08	13	13	06	01	085
AP	07	10	04	06	04	10	05	02	048
AN	04	11	03	05	04	09	04	00	040
S	11	23	05	10	13	16	07	02	087
E	12	06	03	03	01	03	02	00	020

9.3 RELATIONSHIP OF STUDENTS' PERFORMANCE ON DIFFERENT OBJECTIVES

It has already been discussed under the first hypothesis that mean scores go on decreasing (tables 17, 18 and 19) with the increase in different levels of each category, of course, with the exception of erratic behaviour of Synthesis category and the non-independence of Analysis category. The magnitude of correlation also decreases, of course, with the same exceptions, as the categories become increasingly remote in the structure. In fact, if the category of Synthesis is not considered, the picture becomes more transparent and the decrease in the magnitude of correlations from one category to the other becomes more evident. Nevertheless, hierarchical position of Analysis and Synthesis in particular does not fit in properly in the theoretically expected order. It is apparent that the adjacent categories should have the greatest portion of shared elements by virtue of which the highest correlation between them is expected. Any definite inference if drawn from the simple magnitude of correlations, regarding the cumulative nature of the hierarchy, will be hasty. Picture becomes clearer when the correlation matrix is examined in terms of simplical structure the discussion of which follows.

9.4 GUTTMAN'S RADEX TECHNIQUE

The hierarchical cumulative property of the taxonomy can be investigated by Guttman's Radex/Simplex technique. According to this theory if the taxonomy levels are successively more complex than matrix of intercorrelations should exhibit a simplical structure. The hypothesis of hierarchical order for the taxonomy categories, then, lends itself to examination by simplex analysis. According to Guttman's simplex theory if a perfect simplex exists, then :

$$r_{ik.j}=0 \text{ for } i<j<k$$

or

$$r_{ik}=r_{ij}\ r_{jk}, \text{ where } i<j<k$$

In a perfect simplex this relationship holds good for all *i*, *j* and *k*. The hypothesised relationship among the 6 objectives can be depicted as under :

$$r_{12}>r_{13}>r_{14}>r_{15}>r_{16}$$
$$(r_{21}=r_{23})>r_{24}>r_{25}>r_{26}$$
$$(r_{32}=r_{34})>(r_{31}=r_{35})>r_{36}$$
$$(r_{43}=r_{45})>(r_{42}=r_{46})>r_{41}$$
$$(r_{56}=r_{54})>r_{53}>r_{52}>r_{51}$$
$$r_{65}>r_{64}>r_{63}>r_{62}>r_{61}$$

If the relationship is satisfied the correlation matrix will be such that the largest values will lie along the upper-left, lower-right diagonal followed by the next largest values in the adjacent diagonals and the smallest values in the upper-right and lower-left corners of the matrix. This condition is such that the column totals in a perfect simplex will be smallest at the left and right extremes and highest for the central columns. When the correlation matrix approaches the simplex but does not satisfy the rigorous requirements of the perfect simplex the matrix may be classified as quasi-simplex.

Correlation matrices for all the eight schools in respect of classes IX, X and XI were also developed and examined for the simplical structure. These are shown in Annexure (a-h). It is observed that out of 24 matrices, three meet the requirement of the simplex while five do not show any evidence of simplical structure. In four cases if 'Synthesis' is not considered, they also meet the requirement of a simplex. The remaining 12 matrices meet partially the requirement of the simplex and may, therefore, be called quasi-simplical in their structure.

Three correlation matrices, one for each class, i.e., combined for all schools, arising from the administration of the same test consisting of six sub-tests based on each of the six categories of the taxonomy were also prepared (table 27) and subjected to simplical analysis. None of these matrices satisfied the requirements of a perfect simplex. However, three out of six categories, viz., Knowledge, Comprehension and Application are ordered correctly according to Guttman's complexity definition. Synthesis is completely out of place as the values in all the three matrices do not conform to hierarchical structure. Position of Analysis is also erratic. If 'Synthesis' category goes out the matrices by and large reflect quasi-simplical structure. According to Keopp, Stoker, and Bashaw (1966) :

> "If data are gathered to measure the six cognitive levels and if these data do yield a quasi-simplical structure, than this is evidence of the hypothesised hierarchy of complexity"

Thus the null hypothesis 'that the hierarchy is not cumulative' can be said to have been rejected to a great extent keeping in view the ample evidence about the simplical structure revealed through Guttman's Radex technique.

9.5 OBJECTIVE-WISE CUMULATIVE SCORES

In order to test the hypothesis of cumulative nature of the taxonomy analysis of cumulative scores over the objectives was undertaken with 100 students of class XI. According to the hypothesised frequency distribution in such a case of hierarchy, the number of students attempting an item should go on decreasing from Knowledge to Evaluation. This may be taken as absolute scores which go on declining in an inverse order of complexity of objectives. Since these scores may not represent the exclusive number of students who have done the items correctly on the preceding categories too, this score may include correct responses on a higher category although some of the students might not have attempted correctly the items on the lower category.

To determine the real cumulative scores at various levels (K-E) K score, however, remaining the same in both cases, concept-wise count was made at each successive category only of those students who had done an item/items correctly on the preceding level/s. In this way cumulative scores were identified for each set (K-E) of 6 items relating to each concept (1-10) on which the items were based. These were compared with absolute scores on each objective. These are given in table 28. In each set pertaining to a concept four rows of scores are shown under each objective C to E. First row for example gives the cumulative scores of 82, 34, 28, 21 and 20 under each objective with a total (185) in the margin. The third row gives absolute scores which represents actually the number of students attempting the items

Table 27

INTER OBJECTIVE CORRELATION MATRIX SHOWING QUASI SIMPLICAL STRUCTURE

CLASS—IX N=321

Objectives	K	C	AP	AN	S	E
K	—	0.53	0.53	0.45	0.56	0.38
C	0.53	—	0.48	0.50	0.49	0.38
AP	0.53	0.48	—	0.45	0.54	0.53
AN	0.45	0.50	0.45	—	0.52	0.47
S	0.56	0.49	0.54	0.52	—	0.50
E	0.38	0.38	0.53	0.47	0.50	—
Totals	2.45	2.38	2.53	2.39	2.61	2.26

CLASS—X N=291

Objectives	K	C	AP	AN	S	E
K	—	0.44	0.41	0.31	0.44	0.29
C	0.44	—	0.52	0.43	0.56	0.45
AP	0.41	0.52	—	0.48	0.54	0.48
AN	0.31	0.43	0.48	—	0.50	0.44
S	0.44	0.56	0.54	0.50	—	0.59
E	0.29	0.45	0.48	0.44	0.59	—
Totals	1.89	2.40	2.45	2.16	2.63	2.25

CLASS—XI N=200

Objectives	K	C	AP	AN	S	E
K	—	0.56	0.56	0.38	0.48	0.52
C	0.56	—	0.60	0.45	0.53	0.48
AP	0.56	0.60	—	0.59	0.70	0.66
AN	0.38	0.45	0.59	—	0.56	0.56
S	0.48	0.53	0.70	0.56	—	0.66
E	0.52	0.48	0.66	0.56	0.66	—
Totals	2.50	2.62	3.11	2.54	2.93	2.88

correctly in each of the six categories of objectives. Since the frequency in case of K would remain unchanged whether it is absolute or cumulative score, that score is kept outside the matrix and is not counted for calculating chi-square later on. The second and fourth rows represent the contingent expected scores which are calculated on the basis of total scores (185) and (330) in relation to a grand total of 515 in the first example. Thus the figure (60) under C is calculated by $\frac{185 \times 165}{515} = 82$ while figure of (48) in fourth row is obtained from the calculation $\frac{330 \times 75}{515} = 48$. In this way all the figures were calculated as shown in table 28.

Chi-square were computed for each set consisting of 10 pairs of cumulative and the absolute scores to find out the significance of difference between the two sets of scores tabulated in four rows and five columns. Thus 50 chi-squares, 10 on each of the five objectives (C-E) relating to the 10 concepts are given in table 29. The other 10 are given under the totals are the summed up chi-squares one for each concept (1-10).

Table 28

CONCEPT-WISE CUMULATIVE SCORES ON DIFFERENT OBJECTIVES

CLASS XI N=100

Concept No.	K	C	AP	AN	S	E	Total
I	95	082 (060)	034 (027)	028 (038)	021 (032)	020 (028)	185
	95	083 (105)	041 (048)	078 (068)	070 (059)	058 (050)	330
		165	075	106	091	078	515
II	82	58 (41)	38 (29)	31 (29)	26 (31)	18 (23)	171
	82	70 (87)	53 (62)	60 (62)	70 (65)	53 (48)	366
		128	091	091	096	071	537
III	80	29 (15)	18 (14)	13 (16)	09 (16)	07 (14)	076
	80	29 (43)	38 (42)	49 (46)	52 (45)	49 (42)	217
		058	056	062	061	056	293

Concept No.	K	C	AP	AN	S	E	Total
IV	90	17 (68)	77 (67)	51 (53)	41 (52)	26 (33)	272
	90	83 (92)	80 (90)	73 (71)	80 (69)	51 (44)	367
		160	157	124	121	077	639
V	69	53 (41)	38 (33)	26 (28)	24 (31)	19 (27)	160
	69	68 (80)	59 (64)	56 (54)	67 (60)	60 (52)	310
		121	097	082	091	079	470
VI	86	76 (65)	59 (58)	49 (50)	43 (49)	15 (20)	242
	86	80 (91)	79 (80)	70 (69)	73 (67)	33 (28)	335
		156	138	119	116	048	577
VII	89	67 (62)	54 (61)	76 (54)	19 (28)	12 (23)	228
	89	69 (74)	78 (71)	42 (64)	42 (33)	38 (27)	269
		136	132	118	061	050	497
VIII	75	68 (58)	43 (39)	31 (35)	28 (38)	13 (18)	183
	75	85 (95)	59 (63)	61 (57)	59 (54)	35 (30)	299
		153	102	092	087	048	482

Concept No.	K	C	AP	AN	S	E	Total
IX	82	63	47	34	30	25	199
		(52)	(41)	(35)	(37)	(35)	
	82	69	56	55	63	63	306
		(80)	(62)	(54)	(56)	(53)	
		132	103	089	093	088	505
X	52	34	26	04	04	04	072
		(20)	(18)	(05)	(15)	(14)	
	52	50	48	15	57	55	225
		(64)	(56)	(14)	(46)	(45)	
		84	74	19	61	59	297

Table 29

CONCEPT-WISE CHI SQUARE FOR CUMULATIVE SCORES ON DIFFERENT OBJECTIVES

Concept No.	C	AP	AN	S	E	Total
1.	12.677*	2.836	4.103	5.832	3.566	29.014
2.	10.371*	4.099	0.170	0.883	1.191	16.714
3.	17.625*	1.524	0.759	5.152	4.667	29.727
4.	02.790	2.361	0.111	3.267	2.074	10.603
5.	05.310	1.149	0.217	2.397	3.600	12.673
6.	03.192	0.030	0.035	0.035	2.143	05.435 (NS)
7.	00.741	1.493	16.526*	5.348	9.742	33.850
8.	02.777	0.664	0.738	1.221	2.222	07.622 (NS)
9.	03.840	1.459	0.048	2.199	4.743	12.289
10.	12.853*	4.699	0.271	10.697*	9.365	37.895

df=4

Out of 10 chi square values (totals) only two are non-significant (NS). All the other 8 are highly significant. This means that the observed difference between cumulative scores and absolute scores cannot be attributed to mere chance. It would mean that there are many cases where a student who has failed on a lower objective but has done the higher objective item based on the same concept correctly, thereby demonstrating that learning is not necessarily cumulative in terms of the hypothesised hierarchy. On this account the null hypothesis is retained.

9.6 FACTOR ANALYSIS OF INTER-OBJECTIVE CORRELATION MATRICES

Another method of getting evidence about the cumulative hierarchy is the ascertaining of factor pattern. As Kropp, Stocker and Bashaw (1966) have hypothesised, there should be one general factor, four group factors and a unique factor. The pattern of hypothesised leading should be as follows :

Objective	**F_1 (K)**	**F_2 (C)**	**F_3 (AP)**	**F_4 (AN)**	**F_5 (S)**	**F_6 (E)**
Knowledge	×					
Comprehension	×	×				
Application	×	×	×			
Analysis	×	×	×	×		
Synthesis	×	×	×	×	×	
Evaluation	×	×	×	×	×	×
	↓ General Factor	←————	4 Group Factors		————→	↓ Unique Factor

9.6.1 PRINCIPAL COMPONENT METHOD

To know the structure underlying the correlation among different objectives for the classes IX, X and XI, the correlation matrices were subjected to factorial analysis. The method of Principal Components was applied in the first instance. Six factors were extracted but the eigen-values as given below indicated that only the first factor was significant since all other eigenvalues are found to be less than one :

IX N=321	4.412	0.681	0.579	0.490	0.417	0.395
X N=291	4.298	0.753	0.576	0.509	0.471	0.371
XI N=200	4.764	0.691	0.491	0.431	0.326	0.279

(i) *CLASS—IX* :

In Table 30, Loadings as obtained in the seven factors (Unrotated) are given below :

Table 30

FACTOR MATRIX (7 FACTORS)

Variables	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**h^2**
K	0.765	−0.378	−0.274	0.188	−0.030	−0.399	−0.036	1.000
C	0.745	−0.380	0.198	−0.420	0.250	0.115	−0.032	1.000
AP	0.770	0.137	−0.365	−0.261	−0.388	0.186	−0.022	1.000
AN	0.743	0.068	0.569	0.123	−0.314	−0.070	−0.027	1.000
S	0.805	0.030	−0.080	0.421	0.190	0.361	−0.040	1.000
E	0.708	0.601	0.022	−0.127	0.259	−0.229	−0.027	1.000
Total	0.989	−0.027	0.001	0.031	0.030	−0.001	−0.142	1.000

It was observed that in addition to the first factor, high (above 0.20) loadings have been obtained in case of some other factors as well. Factor-2 has given high loadings on Evaluation followed by negative loadings on Knowledge and Comprehension. Factor-3 has given high loadings on Analysis followed by negative loadings on Application and Knowledge. In Factor-4 high loading on Synthesis is followed by almost equally high negative loadings on Comprehension is observable. Factor-5 has given a high negative loading on Application followed by a high loading on Analysis in the same direction. Factor-6 has given high negative loadings on Knowledge and high positive loadings on Synthesis.

Loadings on all other variables are almost insignificant. This shows that the specific components of each of the variables are fairly high which is obvious from the rotated pattern of loadings as given in the following Table 31.

Table 31

ROTATED FACTOR MATRIX (7 FACTORS)

Variables	F_1	F_2	F_3	F_4	F_5	F_6	F_7	h^2
K	0.902	0.128	0.164	−0.225	−0.206	0.225	0.003	1.000
C	0.221	0.133	0.206	−0.910	−0.179	0.178	0.005	1.000
AP	0.218	0.232	0.164	−0.192	−0.890	0.209	0.008	1.000
AN	0.165	0.196	0.909	−0.207	−0.155	0.203	0.006	1.000
S	0.236	0.210	0.212	−0.186	−0.206	0.882	0.007	1.000
E	0.127	0.921	0.190	−0.132	−0.212	0.195	0.007	1.000
Total	0.431	0.368	0.381	−0.407	−0.358	0.452	0.189	1.000

(ii) *CLASS—X* :

Factor matrix of class X (Unrotated) is given in the following Table 32.

Table 32

FACTOR MATRIX (7 FACTORS)

Variables	F_1	F_2	F_3	F_4	F_5	F_6	F_7	h^2
K	0.636	0.693	−0.063	0.317	0.052	−0.088	−0.028	1.000
C	0.771	0.154	0.137	−0.451	−0.364	−0.163	−0.031	1.000
AP	0.775	−0.020	−0.105	−0.315	0.536	0.031	−0.026	1.000
AN	0.704	−0.307	−0.600	0.130	−0.166	−0.071	−0.024	1.000
S	0.827	−0.088	0.176	0.106	−0.120	0.500	−0.033	1.000
E	0.732	−0.383	0.388	0.279	0.080	−0.285	0.027	1.000
Total	0.991	0.025	0.008	0.007	−0.010	0.002	0.127	1.000

As in class IX the highest factor loadings on the first factor were again observed. Besides this, appreciable factor loadings have also been observed in case of other factors. Factor-2 has higher positive loading on Knowledge followed by negative loadings on Evaluation and Analysis. Factor-3 has high negative loadings on Analysis followed by positive loadings on Evaluation. Factor-4 has high negative loadings on Comprehension followed by positive loadings on Knowledge. Factor-5 has high positive loading on Application followed by negative loadings on Comprehension. Factor-6 has high positive loadings on Synthesis followed by negative loadings on Evaluation. Loading on all other variables are almost insignificant. This shows that specific components of each of the variables are fairly high which is obvious from the rotated pattern of loadings given in following Table 33.

Table 33

ROTATED FACTOR MATRIX (7 FACTORS)

Variables	F_1	F_2	F_3	F_4	F_5	F_6	F_7	h^2
K	0.094	−0.949	−0.109	−0.174	0.153	0.155	0.005	1.000
C	0.174	0.195	−0.164	−0.903	0.208	0.214	0.002	1.000
AP	0.195	0.175	−0.204	−0.213	0.897	0.197	0.004	1.000
AN	0.176	0.116	−0.928	−0.158	0.189	0.182	0.005	1.000
S	0.271	0.191	−0.213	−0.239	0.214	0.861	0.001	1.000
E	0.916	0.100	−0.180	−0.170	0.185	0.232	0.005	1.000
Total	0.397	0.384	−0.375	−0.426	0.400	0.430	0.170	1.000

The results are therefore very much similar to those of class IX.

(iii) *CLASS—XI* :

Factor matrix of class XI (Unrotated) is given below in Table 34.

Table 34

FACTOR MATRIX (7 FACTORS)

Variables	F_1	F_2	F_3	F_4	F_5	F_6	F_7	h^2
K	0.727	−0.532	0.207	0.346	−0.138	−0.079	0.024	1.000
C	0.758	−0.378	−0.425	−0.228	0.215	−0.048	0.024	1.000
AP	0.873	0.040	0.029	−0.139	−0.194	0.422	0.025	1.000
AN	0.744	0.438	−0.338	0.367	−0.039	−0.058	0.028	1.000
S	0.834	0.195	0.160	−0.323	−0.221	−0.296	0.027	1.000
E	0.816	0.183	0.356	0.032	−0.415	0.032	0.019	1.000
Total	0.992	0.001	−0.025	0.013	−0.019	−0.010	−0.119	1.000

Like classes IX and X the highest factor loading is on the first factor. In addition high loadings are also observed on some other factors. Factor-2 has high negative loadings on Knowledge followed by positive loading on Analysis and negative loading on Comprehension. Factor-3 has high negative loading on Comprehension followed by positive loading on Evaluation and negative loadings on Analysis. Factor-4 has high positive loading on Analysis. This is followed by positive loading on Knowledge, negative loading on Synthesis and Comprehension respectively. Factor-5 has high loading on Evaluation followed by negative loading on Synthesis and positive loading on Comprehension. Factor-6 has high positive loading on Application followed by negative loading on Synthesis.

Loadings on all other variables are almost insignificant (less than 0.20) . This again shows that specific components of each of the variables are fairly high which is obvious from the rotated factor matrix given in the following Table 35.

Table 35

ROTATED FACTOR MATRIX (7 FACTORS)

Variables	F_1	F_2	F_3	F_4	F_5	F_6	F_7	h^2
K	0.157	−0.913	−0.126	−0.240	0.190	0.180	−0.004	1.000
C	0.188	−0.249	−0.177	−0.898	0.154	0.109	−0.004	1.000
AP	0.306	−0.247	−0.266	−0.266	0.268	0.795	−0.003	1.000
AN	0.204	−0.123	−0.912	−0.170	0.210	0.192	−0.003	1.000
S	0.849	−0.180	−0.242	−0.212	0.276	0.258	−0.002	1.000
E	0.271	−0.221	−0.247	−0.170	0.857	0.226	−0.005	1.000
Total	0.420	−0.395	−0.429	−0.404	0.379	0.390	−0.155	1.000

The results are showing the same pattern in classes X and XI.

9.6.2 USE OF CENTROID METHOD

Another method of centroid factor analysis was applied to Class IX data. Only two factors were found to be significant. The unrotated factor loadings are given below in Table 36.

Table 36

UNROTATED FACTOR LOADINGS

Variables	F_1	F_2	h^2
K	0.709	0.045	0.504
C	0.690	−0.206	0.518
AP	0.724	0.197	0.562
AN	0.690	−0.177	0.507
S	0.748	0.111	0.572
E	0.661	0.130	0.454

There were subjected to orthogonal rotation and the rotated factor loadings are given below in Table 37.

Table 37

ROTATED FACTOR LOADINGS

Variables	F_1	F_2	h^2
K	0.666	0.246	0.504
C	0.720	0.000	0.518
AP	0.637	0.396	0.562
AN	0.712	0.027	0.507
S	0.685	0.320	0.572
E	0.596	0.314	0.454

Here again it is found that the first factor gives high loading on all the six variables which only indicates that a general factor has played a significant part in case of all variables.

Second factor has given significant loadings on Knowledge, Application, Synthesis and Evaluation which may be due to some kind of group factor.

A look at the communalities indicates that maximum common variance is 57% in respect of Synthesis and the major portion of this common variance is contributed by the general factor. Therefore, specific variance is again quite large in case all the six variables. This has been demonstrated very effectively through Principal Components Analysis as stated earlier, and is even true about Classes X and XI. Therefore, the hypothesised structure in the form of one general factor, one unique factor and four group factor to support the postulate of cumulative hierarchy, does not get substantiated by the obtained data.

9.7 McQUITTY'S SYNDROME ANALYSIS

In this study use of McQuitty's (1960) Hierarchical Syndrome Analysis was made to verify the cumulatively hierarchical nature of the taxonomy. According to Smith (1968) :

> "Hierarchical classification by reciprocal pairs is a statistical method of classifying people, institutions or other elements into a hierarchical system based on indices of association between them .... Hierarchical classification is designed to improve and purify data as it proceeds ; each successive category is intended to become a better representative of a type as it exists in theory. The method involves the selection of pairs of objects which are indicative of types, i.e. ; have common characteristics. It then expands and improves the type by incorporating additional objects and eliminating characteristics which are irrelevant to the description of types."

The data analysed in this study pertains to only Class IX inter-objective correlation matrix. The inter-correlations of subtests representing K, C, A (AP), N (AN), S and E were subjected to hierarchical Syndrome Analysis (McQuitty, 1966), highest pair version.

The purpose was to classify the objectives into a hierarchical system of syndromes. For this Table 38 was developed indicating the agreement correlation coefficients (decimals removed) on the basis of highest pair version. On the basis of this table a diagram representing the hierarchical system of syndromes as shown in Fig. 8 was developed. This figure shows different patterns of association. Two major classification patterns are as under :

(i) K-1-6-10-13-15
OR
K-S-A-C-N-E
K-S-A-C-N ↗
K-S-A-C ↗
K-S-A ↗
K-S ↗
K ↗

Pattern-1

(ii) S-5-9-12-14
OR
S-N-C-A-E
S-N-C-A ↗
S-N-C ↗
S-N ↗
S ↗

Pattern-2

The two patterns if combined given an overall picture of the pattern of syndromes as under :

Two Emerging Patterns

(i) K S A C N E
OR
K
K+S
K+S+A
K+S+A
K+S+A+C
K+S+A+C+N
K+S+A+C+N+E

Pattern-1

(ii) K S N C A E
OR
K
K+S
K+S+N
K+S+N+C
K+S+N+C+A
K+S+N+C+A+E

Pattern-2

The analysis, therefore, reveals that 'Knowledge' forms the bottom and 'Evaluation', the top category—'Synthesis' falls adjacent to 'Knowledge' but below 'Analysis', 'Comprehension' and 'Application'. There is, however, no clearcut hierarchy established in case of Analysis, Comprehension and Application. Application and Analysis seem to overlap as also the Comprehension and Application. Thus the hierarchy is clear only in case of K, S and E whereas the middle range of objectives do not exhibit a distinct hierarchy. Therefore, the final arrangement on cumulativeness can be rewritten as under :

K ———→ S ———→ (NCA) ———→ E

Table 38

INTER-OBJECTIVE AGREEMENT CORRELATIO-COEFFICIENT MATRICS

Class IX Objectives	K	C	A	N	S	E	1 KS	2 SA	3 KC	4 AE	5 SN	6 KSA	7 KSC	8 SAE	9 SNC	10 KSCA	11 SNAE	12 SNCA	13 KSACN	14 SNCAE	KSNCAE OR 15 KSACNE
K	—	283	276	200	318	145	—	276	—	145	200	—	—	145	200	—	145	200	—	145	
C	283	—	234	252	236	146	236	234	—	146	236	234	—	146	—	—	146	—	—	—	
A	276	234	—	203	289	277	276	—	234	—	203	—	234	—	203	—	—	—	—	—	
N	200	252	203	—	272	225	200	203	200	203	—	200	200	203	—	200	—	—	—	—	
S	318	236	289	272	—	254	—	—	236	254	—	—	—	—	—	—	—	—	—	—	
E	145	146	277	225	254	—	145	254	145	—	225	145	145	—	146	145	—	146	145	—	
1. KS	—	236	276	200	—	145	—	276	236	145	200	—	—	145	200	—	145	200	—	—	
2. SA	276	234	—	203	—	254	276	—	234	254	203	—	234	—	203	—	—	—	—	—	
3. KC	—	—	234	200	236	145	236	234	—	145	200	234	—	145	200	—	145	200	—	—	
4. AE	145	146	—	203	254	—	145	254	145	—	203	145	145	—	145	145	—	—	—	—	
5. SN	200	236	203	—	—	225	200	203	200	203	—	200	200	203	—	200	—	—	—	—	
6. KSA	—	234	—	200	—	145	—	—	234	145	200	—	234	145	200	—	145	—	—	—	
7. KSC	—	—	234	200	—	145	—	234	—	145	200	234	—	145	200	—	145	200	—	—	
8. SAE	145	146	—	203	—	—	145	—	145	—	203	145	145	—	146	145	—	146	—	—	
9. SNC	200	—	203	—	—	146	200	203	200	145	—	200	200	146	—	—	—	—	—	—	
10. KSCA	—	—	—	200	—	145	—	—	—	145	200	—	—	145	—	—	145	—	—	—	
11. SNAE	145	146	—	—	—	—	145	—	145	—	—	145	145	—	—	145	—	—	—	—	
12. SNCA	200	—	—	—	—	146	200	—	200	—	—	—	200	146	—	—	—	—	—	—	
13. KSACN	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
14. SNCAE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
15. KSACNE OR KSNCAE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

Thus the null hypothesis so framed is neither fully substantiated nor rejected outright. The evidence does not support the claimed cumulative hierarchy but for the position of 'Knowledge' and 'Evaluation' categories.

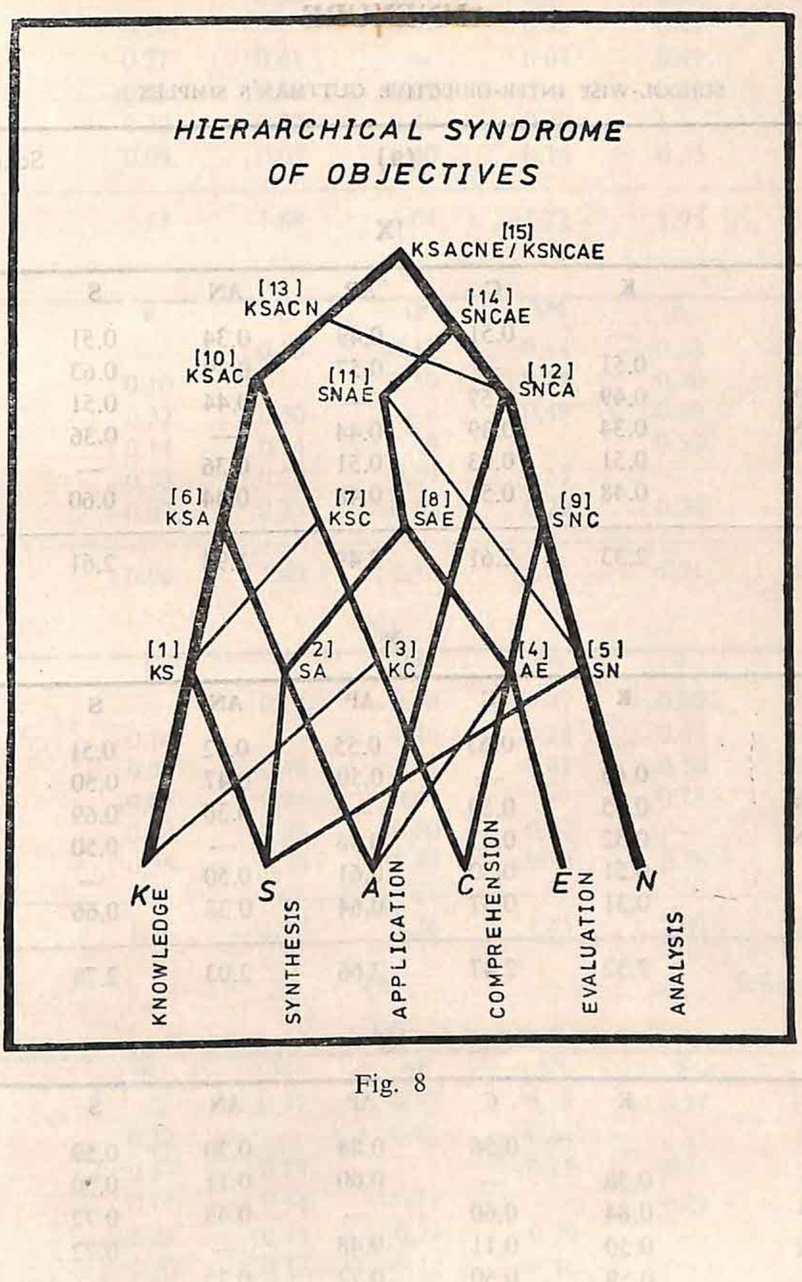

Fig. 8

ANNEXURE

SCHOOL-WISE INTER-OBJECTIVE GUTTMAN'S SIMPLEX

(a) School No. 1

IX

	K	C	AP	AN	S	E
K	—	0.51	0.49	0.34	0.51	0.48
C	0.51	—	0.57	0.39	0.63	0.51
AP	0.49	0.57	—	0.44	0.51	0.48
AN	0.34	0.39	0.44	—	0.36	0.44
S	0.51	0.63	0.51	0.36	—	0.60
E	0.48	0.51	0.48	0.44	0.60	—
	2.33	2.61	2.49	1.94	2.61	2.51

X

	K	C	AP	AN	S	E
K	—	0.63	0.55	0.32	0.51	0.31
C	0.63	—	0.50	0.47	0.50	0.39
AP	0.55	0.50	—	0.36	0.69	0.64
AN	0.32	0.47	0.36	—	0.50	0.38
S	0.51	0.50	0.61	0.50	—	0.66
E	0.31	0.37	0.64	0.38	0.66	—
	2.32	2.47	2.66	2.03	2.78	2.36

XI

	K	C	AP	AN	S	E
K	—	0.58	0.84	0.30	0.59	0.72
C	0.58	—	0.60	0.11	0.50	0.48
AP	0.84	0.60	—	0.48	0.72	0.65
AN	0.30	0.11	0.48	—	0.72	0.59
S	0.59	0.50	0.72	0.72	—	0.80
E	0.72	0.48	0.65	0.59	0.80	—
	3.03	2.27	3.29	2.20	3.33	3.24

(b) School No. 2

IX

	K	C	AP	AN	S	E
K	—	0.50	0.27	0.39	0.39	0.08
C	0.50	—	0.41	0.32	0.43	0.02
AP	0.27	0.41	—	0.07	0.49	0.40
AN	0.39	0.32	0.07	—	0.29	0.15
S	0.39	0.43	0.49	0.29	—	0.35
E	0.08	0.02	0.40	0.15	0.35	—
	1.63	1.68	1.64	1.22	1.95	1.00

X

	K	C	AP	AN	S	E
K	—	0.10	0.32	0.14	—0.33	—0.07
C	0.10	—	0.50	0.34	0.20	0.35
AP	0.32	0.50	—	0.49	0.29	0.52
AN	0.14	0.34	0.49	—	0.55	0.29
S	—0.33	0.20	0.29	0.55	—	0.34
E	—0.07	0.35	0.52	0.29	0.34	—
	0.96	1.49	2.12	1.81	1.71	1.57

XI

	K	C	AP	AN	S	E
K	—	0.14	0.40	—0.07	0.30	0.35
C	0.14	—	0.46	0.34	0.48	0.50
AP	0.40	0.46	—	0.41	0.50	0.49
AN	—0.07	0.34	0.41	—	0.25	0.38
S	0.30	0.48	0.50	0.25	—	0.56
E	0.35	0.50	0.49	0.38	0.56	—
	1.26	1.92	2.26	1.45	2.09	2.28

(c) School No. 3

IX

	K	C	AP	AN	S	E
K	—	0.31	0.37	0.18	0.27	—0.10
C	0.31	—	0.13	0.44	0.35	0.18
AP	0.37	0.13	—	—0.15	0.21	—0.12
AN	0.18	0.44	—0.15	—	0.29	0.16
S	0.27	0.35	0.21	0.29	—	0.33
E	—0.10	0.18	—0.12	0.16	0.33	—
	1.23	1.41	0.08	1.22	1.45	0.89

X

	K	C	AP	AN	S	E
K	—	0.40	0.33	0.07	0.33	0.41
C	0.40	—	0.62	0.46	0.56	0.45
AP	0.33	0.62	—	0.49	0.51	0.41
AN	0.07	0.46	0.49	—	0.65	0.53
S	0.33	0.56	0.51	0.65	—	0.78
E	0.41	0.45	0.41	0.53	0.78	—
	1.54	2.49	2.36	2.20	2.83	2.58

XI

	K	C	AP	AN	S	E
K	—	0.64	0.46	0.34	0.40	0.51
C	0.64	—	0.53	0.51	0.48	0.48
AP	0.46	0.53	—	0.38	0.66	0.70
AN	0.34	0.51	0.38	—	0.32	0.56
S	0.40	0.48	0.66	0.32	—	0.67
E	0.51	0.48	0.70	0.56	0.67	—
	2.35	2.64	2.73	2.11	2.53	2.92

(d)

School No. 4

IX

	K	C	AP	AN	S	E
K	—	0.18	0.29	0.10	0.62	0.18
C	0.78	—	0.17	0.59	0.34	0.30
AP	0.29	0.17	—	0.11	0.57	0.30
AN	0.10	0.59	0.11	—	0.22	0.34
S	0.62	0.34	0.57	0.22	—	0.33
E	0.18	0.30	0.30	0.34	0.33	—
	1.37	1.58	1.44	1.36	2.08	1.45

X

	K	C	AP	AN	S	E
K	—	0.50	0.47	0.38	0.47	0.25
C	0.50	—	0.47	0.60	0.65	0.47
AP	0.47	0.47	—	0.62	0.65	0.66
AN	0.38	0.60	0.62	—	0.57	0.72
S	0.47	0.65	0.65	0.57	—	0.72
E	0.25	0.47	0.66	0.72	0.72	—
	2.07	2.69	2.87	2.89	3.06	2.82

XI

	K	C	AP	AN	S	E
K	—	0.69	0.56	0.55	0.46	0.61
C	0.69	—	0.70	0.64	0.70	0.65
AP	0.56	0.70	—	0.73	0.71	0.77
AN	0.55	0.64	0.73	—	0.71	0.68
S	0.46	0.70	0.71	0.71	—	0.68
E	0.61	0.65	0.77	0.68	0.68	—
	2.87	3.38	3.47	3.31	3.26	3.39

(e)

School No. 5

IX

	K	C	AP	AN	S	E
K	—	0.53	0.42	0.50	0.41	0.43
C	0.53	—	0.78	0.41	0.49	0.44
AP	0.42	0.78	—	0.49	0.61	0.54
AN	0.50	0.41	0.49	—	0.32	0.53
S	0.41	0.49	0.61	0.32	—	0.20
E	0.43	0.44	0.54	0.53	0.20	—
	2.29	2.65	2.84	2.25	2.03	2.14

X

	K	C	AP	AN	S	E
K	—	0.19	0.06	0.22	0.25	−0.07
C	0.19	—	0.34	0.55	0.39	0.51
AP	0.22	0.34	—	0.41	0.39	0.34
AN	0.22	0.55	0.41	—	0.54	0.38
S	0.25	0.39	0.39	0.54	—	0.53
E	−0.07	0.51	0.34	0.38	0.53	—
	0.79	1.98	1.54	2.10	2.10	1.83

XI

	K	C	AP	AN	S	E
K	—	0.46	0.43	0.02	0.37	0.27
C	0.46	—	0.47	0.14	0.34	0.20
AP	0.43	0.47	—	0.29	0.48	0.29
AN	0.02	0.14	0.29	—	0.08	0.18
S	0.37	0.34	0.48	0.08	—	0.42
E	0.27	0.20	0.29	0.18	0.42	—
	1.55	1.61	1.96	0.71	1.69	1.36

(f)

School No. 6

IX

	K	C	AP	AN	S	E
K	—	0.53	0.47	0.35	0.37	0.57
C	0.53	—	0.68	0.49	0.48	0.54
AP	0.47	0.68	—	0.50	0.45	0.63
AN	0.35	0.49	0.50	—	0.45	0.42
S	0.37	0.48	0.45	0.42	—	0.54
E	0.57	0.54	0.63	0.41	0.54	—
	2.29	2.72	2.73	2.17	2.29	2.70

X

	K	C	AP	AN	S	E
K	—	0.37	0.48	0.52	0.41	0.38
C	0.37	—	0.39	0.46	0.47	0.50
AP	0.48	0.39	—	0.62	0.60	0.57
AN	0.52	0.46	0.62	—	0.74	0.57
S	0.41	0.47	0.60	0.74	—	0.60
E	0.38	0.50	0.57	0.57	0.60	—
	2.16	2.19	2.66	2.91	2.82	2.62

XI

	K	C	AP	AN	S	E
K	—	0.53	0.69	0.64	0.51	0.37
C	0.53	—	0.43	0.44	0.43	0.01
AP	0.69	0.43	—	0.67	0.69	0.54
AN	0.64	0.44	0.67	—	0.58	0.53
S	0.51	0.43	0.69	0.58	—	0.43
E	0.37	0.01	0.54	0.53	0.43	—
	2.74	1.84	3.02	2.86	2.84	1.88

(g)

School No. 7

IX

	K	C	AP	AN	S	E
K	—	0.13	0.45	0.42	0.37	0.37
C	0.13	—	0.17	0.04	0.09	0.15
AP	0.45	0.17	—	0.54	−0.01	0.38
AN	0.42	0.04	0.54	—	0.09	0.53
S	0.37	0.09	−0.01	0.09	—	0.10
E	0.37	0.15	0.38	0.53	0.10	—
	1.74	0.58	2.55	1.62	0.66	1.53

X

	K	C	AP	AN	S	E
K	—	0.29	0.12	0.09	0.51	0.13
C	0.29	—	0.34	0.18	0.47	0.33
AP	0.12	0.34	—	0.10	0.38	0.45
AN	0.09	0.18	0.10	—	0.22	0.32
S	0.51	0.47	0.38	0.22	—	0.46
E	0.13	0.33	0.45	0.32	0.46	—
	1.14	1.61	1.39	0.91	2.04	1.69

XI

	K	C	AP	AN	S	E
K	—	0.43	0.70	0.78	0.84	0.86
C	0.43	—	0.61	0.42	0.52	0.51
AP	0.70	0.61	—	0.89	0.81	0.65
AN	0.78	0.42	0.89	—	0.94	0.66
S	0.84	0.52	0.81	0.94	—	0.78
E	0.86	0.51	0.65	0.66	0.78	—
	3.61	2.49	3.66	3.69	3.89	3.46

(h)

School No. 8

IX

	K	C	AP	AN	S	E
K	—	0.26	0.24	0.00	0.12	0.02
C	0.26	—	0.64	0.52	0.30	0.49
AP	0.24	0.64	—	0.33	0.53	0.40
AN	0.09	0.52	0.33	—	0.44	0.35
S	0.12	0.30	0.53	0.44	—	0.01
E	0.02	0.49	0.40	0.35	0.01	—
	0.73	2.21	2.14	1.73	1.40	1.27

X

	K	C	AP	AN	S	E
K	—	0.50	0.59	0.73	0.34	0.40
C	0.50	—	0.63	0.58	0.40	0.32
AP	0.59	0.65	—	0.44	0.38	0.19
AN	0.73	0.58	0.44	—	0.21	0.12
S	0.34	0.40	0.38	0.21	—	0.44
E	0.40	0.32	0.19	0.12	0.44	—
	2.56	2.45	2.25	2.08	1.77	1.47

XI

	K	C	AP	AN	S	E
K	—	0.35	0.47	0.36	0.17	0.23
C	0.35	—	0.76	0.19	0.62	0.65
AP	0.47	0.76	—	0.52	0.76	0.77
AN	0.36	0.19	0.53	—	0.27	0.22
S	0.17	0.62	0.76	0.27	—	0.70
E	0.23	0.65	0.77	0.22	0.70	—
	1.58	2.57	3.28	1.56	2.52	2.57

10

10.0 VALIDATION OF THE POSTULATE OF LEARNED BEHAVIOUR AND IMPACT OF OBJECTIVE BASED TEACHING

One of the postulates of Bloom's taxonomy of educational objectives is that the mental processes designated in the taxonomy are learned behaviours. Accordingly, it is assumed in this taxonomy that learning is reinforced with practice. As such recurrent use of concepts over a period of time improves one's understanding and manipulativeness. Continual use of feed-back reinforces learning as well as improves transfer of learning. Therefore, the improvement in students' achievement over the grades is the issue that was to be investigated in the present study. For this following Null Hypothesis was formulated.

HYPOTHESIS—3

H : 3 When taxonomy tests are administered to students at different levels (IX, X and XI), their achievement scores in all categories do not differ significantly.

To test this hypothesis following techniques were used :

10.1 Class-wise differences in mean achievement
10.2 Objective-wise differences in mean achievement
10.3 School-wise differences in mean achievement

10.1 CLASS-WISE DIFFERENCES IN MEAN ACHIEVEMENT

To test this hypothesis the means and standard deviations for all the three classes were computed as shown below :

Statistic	Class IX	Class X	Class XI
N	321	291	200
Mean	15.302	21.429	30.420
S.D.	09.430	10.486	12.663

From the above data it is quite obvious that mean score goes on increasing as we proceed from classes IX to XI. To calculate the significance of difference between the means the critical ratios were computed as given below :

Table 39

CRITICAL RATIOS SHOWING SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF CLASSES IX, X AND XI

Mean	Mean	S.D.	S.D.	SE_P	Obt. diff. in means	C.R.	Sig. level
IX	X	IX	X				
15.302	21.429	9.430	10.486	0.809	6.127	7.574	0.01
IX	XI	IX	XI				
15.302	30.420	9.430	12.663	1.039	15.118	14.551	0.01
X	XI	X	XI				
21.429	30.420	10.486	12.663	1.086	8.991	8.279	0.01

From the results shown in Table 39 it is quite evident that the differences between classes IX and X, classes X and XI and classes IX and XI are highly significant which support the viewpoint that cognitive behaviours designated in the taxonomy are learned behaviours, thereby rejecting the null hypothesis outright.

Table 40

SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF DIFFERENT OBJECTIVES FOR CLASSES IX-XI

IX and X

Sl. No.	Objective	Mean	Mean	S.D.	S.D.	$S.E_D$	Obtained difference in means	C.R.	Significance level
1.	K	4.53	5.97	2.69	2.30	0.202	1.44	7.13	0.01
2.	C	3.10	3.98	2.25	2.31	0.184	0.88	4.78	0.01
3.	AP	1.92	2.78	2.38	2.22	0.187	0.86	4.62	0.01
4.	AN	2.31	2.75	2.25	2.14	0.179	0.44	2.46	0.05
5.	S	3.13	4.01	2.70	2.56	0.214	0.88	4.11	0.01
6.	E	1.52	2.31	1.91	2.07	0.161	0.79	4.91	0.01

IX and XI

Sl. No.	Objective	Mean	Mean	S.D.	S.D.	$S.E_D$	Obtained difference in means	C.R.	Significance level
1.	K	4.53	7.37	2.69	2.47	0.232	2.84	12.24	0.01
2.	C	3.10	5.92	2.25	2.53	0.219	2.82	12.88	0.01
3.	AP	1.92	4.38	2.38	2.85	0.243	2.46	10.12	0.01
4.	AN	2.31	4.30	2.25	2.51	0.219	1.99	9.09	0.01
5.	S	3.13	5.54	2.70	2.83	0.251	2.41	9.60	0.01
6.	E	1.52	3.40	1.91	2.44	0.202	1.88	9.31	0.01

X and XI

Sl. No.	Objective	Mean	Mean	S.D.	S.D.	S.E$_D$	Obtained difference in means	C.R.	Significance level
1.	K	5.97	7.37	2.30	2.47	0.221	1.40	6.34	0.01
2.	C	3.98	5.92	2.31	2.53	0.224	1.94	8.66	0.01
3.	AP	2.78	4.38	2.22	2.85	0.241	1.60	6.64	0.01
4.	AN	2.75	4.30	2.14	2.51	0.219	1.55	7.08	0.01
5.	S	4.01	5.54	2.56	2.83	0.251	1.53	6.10	0.01
6.	E	2.31	3.40	2.07	2.44	0.212	1.09	5.14	0.01

10.2 OBJECTIVE-WISE DIFFERENCES IN MEAN ACHIEVEMENT

Apart from class-wise overall performance, the differences and their significance were found out with respect to the six objectives also. The same technique of finding out the C.R. and their significance was adopted as shown in the Table 39.

Out of 18 critical ratios as shown in Table 40 there is none which is not significant. Only one is significant at 0.05 level, i.e., the 'Analysis' category in class IX-X comparison. All the remaining 17 out of 18 are highly significant at 0.01 level. This provides a clear-cut evidence against the tenability of hypothesis of no-difference existing in students' achievement in IX, X and XI.

From the evidence collected above, it is clear that significant differences exist among students' achievement not only in terms of overall performance with respect to each class, but also with respect to each objective. It appears that learning at a lower level gets reinforced when the concepts learnt in lower grades recur in higher grades, sometimes as basis for learning of concepts of higher order in hierarchy and sometimes as a means to learning development of new concepts. In the present study although the syllabus of class XI was different from that of classes X and IX both old and the new syllabi contained the five common Units of teaching on which the test was based. Thus class XI students had learnt these topics in 10th class while the present 10th class students had learnt these topics in class IX. It was only class IX which had finished the learning of those topics, just before they sat for this test. The mean difference between performance of classes X and XI (8.911), as compared to the mean difference between classes IX and X (6.127) is appreciably more. This indicates that one year's gap in the former, in fact, constitutes two years' difference (for XI) in terms of having learnt the biological concepts, used in testing. Continual or recurrent use of those concepts in teaching and learning, must have, therefore, lead to better and thorough learning resulting in higher level of performance.

Nevertheless, the results are based on the assumption that level of students' achievement does not differ significantly from year to year. It is proposed to follow the present class IX now promoted to class X and see if it makes any difference. On the basis of empirical evidence gathered from this study the null hypothesis stands rejected.

10.3 SCHOOL-WISE DIFFERENCES IN MEAN ACHIEVEMENT

As for different schools the similar evidence accrued but for one school and one class. The mean score goes on increasing from class IX to class XI in each of the eight schools. The Table 41 shows clearly the gradual increase in the mean score of students from the three classes.

Table 41

SCHOOL-WISE MEANS OF DIFFERENT CLASSES

	IX	X	XI
School No.	Mean	Mean	Mean
1.	14.59	21.27	34.94
2.	30.59	28.32	40.53
3.	11.68	14.83	23.59
4.	11.11	23.48	26.80
5.	15.72	19.63	25.65
6.	25.22	27.70	41.56
7.	10.10	19.92	40.88
8.	05.52	17.36	28.75

Unusually marked difference in students' performance in classes IX and X in school Nos. 4 and 8 may be attributed again to the lack of reinforcement time available to these 9th class students of the two schools because they had to finish some of the topics just before the test was administered. Those topics would have otherwise been covered in class X. The other reason could be the external examination which is held only at the end of class X and as such the 9th class students are not seriously involved in studies as those of 10th class. One reason especially for school No. 8 was the teaching of topics in undue haste to enable students to take the test. Thus even when school-wise performance is analysed the data supports the postulate of learnt behaviour. The hypothesis of no difference existing in achievement scores of students of different grades (IX to XI) is rejected.

IMPACT OF OBJECTIVE BASED TEACHING

As stated earlier in Chapter-III most of the validation studies undertaken by researchers were based on the assumption that the students are taught well. This assumption is indeed questionable because unless students are taught for development of certain abilities specially the higher level abilities one cannot infer about the hierarchy of different objectives. Therefore, performance of students on different objectives would depend on the development of abilities implied by those objectives, during teaching. Suppose little emphasis in teaching is given on development of higher level abilities like those implied under application, analysis, synthesis and evaluation, most of the students would not be able to attempt questions based on those objectives. It was, therefore, necessary to first teach for the intended objectives and then only test students on those objectives. It was in this context that the following hypothesis was formulated to find out the impact of objective based teaching on the students' attainment on all the six objectives.

HYPOTHESIS—4

H : 4 There is no significant difference in the attainment of objectives categorised as Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation between students taught with the help of objective based instructional materials using both its content and methods and those students who are taught by usual text and traditional methods.

To test this hypothesis following techniques were used :

10.4 Significance of difference between the means of experimental and control groups for overall performance
10.5 Significance in means of two groups, objective-wise
10.6 Significance of difference between the means of high achievers and low achievers
10.7 Analysis of covariance—Pretest and post-test
10.8 Analysis of covariance—Intelligence test, pretest and post-test

In the previous Chapter it has been pointed out that on the basis of half-yearly school examination considered as pretest, and the intelligence test (V and N) the two groups came out to be equivalent. Validity and reliability of the half-yearly examination marks which are used in this study as pretest, can no doubt be questioned. But whatever be its reliability the same common instrument used for both the groups might have affected both the groups equally.

Students from both the groups come from similar socio-economic environments, as the school, by and large, caters to the homes of Indian Institute of Technology and National Council of Educational Research and Training. Thus broadly, the intelligence score, the pretest scores and similar socio-economic status of students was considered as sufficient evidence to declare the two groups equivalent for instructional intervention. The statistical data and results on the basis of which the experimental and control groups were declared equivalent are given below :

Groups	**Experimental**		**Control**		**Mean diff.**	**S.D.**	**C.R.**
	Mean	**S.D.**	**Mean**	**S.D.**			
Intelligence test (V and N)	69.58	11.20	70.17	12.20	0.59	3.087	0.638
Pretest (School marks)	25.50	11.947802	27.47	12.971076	1.97	3	0.219

In neither of these two tests the difference in means is significant thereby providing the needed evidence in support of equivalence of the two groups which formed the sample-B to test the hypothesis regarding impact of objective based instruction on students' achievement.

10.4 DIFFERENCE IN OVERALL PERFORMANCE

To test the proposed hypothesis, the means and standard deviations of the pretest and post-test were computed, significance of differences between the means were calculated t-test was applied to the post-test achievement scores. The post-test achievement means and standard deviations are given below :

	Experimental group	Control group	$S.E_D$	Mean diff.	C.R.
Mean	17.50	11.60	2.70	5.90	2.185
S.D.	11.81	10.14			

C.R. is 2.185 which is clearly significant at 0.05 level. C.R. does not reach 2.58 and hence is not significant at 0.01 level but is significant at 0.02 level and, therefore, can be accepted at this level. The observed increase in the means in favour of experimental group may be said to have occurred due to deliberately planned and carried out objective based instruction that resulted in improvement as compared to the control group in respect of overall performance on the test. Thus the significant difference of the two means indicates that the hypothesis is not tenable.

10.5 DIFFERENCE IN OBJECTIVE-WISE PERFORMANCE

In addition to analysis of overall performance attempt was made to compare the two groups in respect of students' performance on different taxonomic objectives. As usual means, standard deviations and t-values were computed to find out the significance of difference among the means. Following table depicts the data of two groups.

Table 42

OBJECTIVE-WISE DIFFERENCES IN MEANS OF EXPERIMENTAL AND CONTROL GROUP

Group Objective	Experimental		Control		t-Value	Level of significance
	Mean	S.D.	Mean	S.D.		
1. Knowledge	5.06	2.71	4.53	2.65	1.39	Not significant
2. Comprehension	4.31	2.23	2.28	2.01	5.80	0.01
3. Application	2.39	2.29	1.43	2.03	2.74	0.01
4. Analysis	2.28	1.82	2.30	1.87	0.06	Not significant
5. Synthesis	3.31	2.37	2.50	1.28	2.45	Significant
6. Evaluation	1.50	1.66	0.93	1.55	1.90	Not significant
Overall	18.85		13.97			

From the above table the following interpretation can be made :

(i) That objective based instruction involved various levels of interaction for developing different abilities as implied by various objectives, does improve students' performance as the means of the two groups indicate with the exception, however, of 'Analysis', and 'Evaluation' categories. The significant difference in case of 'Synthesis' if interpreted in the light of earlier conclusion about the placement of this category, is nothing but the impact at Comprehension level.

(ii) Non-significant value with respect to 'Knowledge' category shows that teaching for recall of specifics, abstractions and generalisations does not involve any appreciable student-teacher interaction as given in the rationale for teaching plans. Since almost similar pattern of teacher dominated exposition, description or narration is involved in teaching for Knowledge objective no tangible impact of teaching-learning process is there.

(iii) Achievement on Comprehension and Application objectives is clearly indicative of the favourable impact of deliberate attempt of objective-based teaching. Since significance level on 'Synthesis' is almost approaching the 0.01 level, it again provides strong evidence of the effect of process variables on the learning outcomes.

(iv) In case of Evaluation, the difference is not significant. However, the t-value at 0.05 level of significance is 2.00 which is not far away from the one observed (1.90) for 'Evaluation' category. This at least clearly indicates a positive trend. Having given more time for instructional intervention there could be more appreciable difference. Besides, this category being the most complex one as alleged by their authors, must in all probability require development of certain prerequisite abilities which are implied by lower level objectives, say 'Analysis', which might not have been developed adequately. This in turn could effect performance on 'Evaluation' category that should logically require more time to develop additional abilities unique to evaluation.

On the basis of the tangible differences as reflected in the Table 42 the null hypothesis if not clearly rejected on all the objectives, is certainly not tenable. If Analysis category whose behaviour all through is intriguing, is omitted, there is sufficient evidence for the rejection or at least against the sustenance of null hypothesis.

10.6 DIFFERENCE IN PERFORMANCE OF HIGH AND LOW ACHIEVERS

Whether there is any difference between the achievement of high achievers in both the groups was also examined using the same statistical technique. Scores of ten students from each group were taken and critical ratios were calculated as given in Table 43.

Table 43

OBJECTIVE-WISE DIFFERENCE IN HIGH ACHIEVERS OF EXPERIMENTAL AND CONTROL GROUP

			Experimental		Control	
Objectives	K	C	AP	AN	S	E
Mean Difference	1.10	1.90	2.60	—0.10	0.98	0.99
$S.E_D$	0.57	0.58	0.66	0.56	0.67	0.65
C.R.	1.93	3.28	3.94	—0.18	1.46	1.52
Level of significance	NS	0.01	0.01	NS	NS	NS

NS : Not Significant

These results confirm the earlier one discussed with respect to the total sample. Significant difference in case of Comprehension and Application further support the evidence that objective based instruction does improve Comprehension and ability to apply. There is no evidence to show that high achievers may benefit more than others within the same experimental group.

As for low achievers the overall performance shows a mean of 6.80 as against 3.80 of the control group with standard deviations as 0.40 and 0.80 respectively. Mean difference is 3.00 while S.ED is 0.283. C.R. is 10.600.

Thus for the low achievers overall performance improved quite appreciably as C.R. is 10.600 which is very high, thereby showing favourable impact of instructional effect on experimental group.

As for significance of difference between means for the six objectives following Table 44 indicates the data.

Table 44

OBJECTIVE-WISE DIFFERENCE IN LOW ACHIEVERS OF EXPERIMENTAL AND CONTROL GROUP

		Experimental			Control	
Objectives	**K**	**C**	**AP**	**AN**	**S**	**E**
Mean difference	—0.20	1.86	0.00	0.10	0.00	0.22
S.E$_D$	0.84	8.56	0.00	0.49	0.00	0.64
C.R.	0.24	3.32	0.00	0.20	0.00	0.52
Level of significance	NS	0.01	NS	NS	NS	NS

NS : Not Significant

It appears that as far as 'Knowledge' is concerned the instruction had no favourable impact on the experimental group. The same is true of AP, AN, S and E as the C.R. is not significant in either of these cases. However, the difference is significant in case of 'Comprehension'. This shows that if teaching is geared to the intended learning outcomes it does improve achievement of low achievers on Comprehension. Since data used in case of low and high achievers consisted of only 10 cases in each group the results show only a trend and need further supportive evidence using bigger sample to substantiate the findings.

10.7 ANALYSIS OF COVARIANCE (PRETEST AND POST-TEST)

To determine the significance of difference between the means of experimental and control group, technique of analysis of covariance was used with respect to pretest and post-test. Details of the various steps involved are omitted in this write-up. The more relevant data used is as under :

(*i*) *Sums and Means of the Experimental and Control Groups*

Statistic	**Experimental Group IX-A N=36**			**Control Group IX-B N=30**		
	X_1 (Pretest)	**Y_1 (Post-test)**	**X_1Y_1**	**X_2 (Pretest)**	**Y_2 (Post-test)**	**X_2Y_2**
Sums (Σ)	918	630	17204	824	348	9508
Means (Ms)	25.50	17.50	—	27.47	11.60	—

(*ii*) *Analysis of Variance of X and Y Scores taken separately*

Sources of Variation	**df**	**SS_x**	**SS_y**	**$MS_x(V_x)$**	**$MS_y(V_y)$**
Between means	1	3709	2775	3709	2775
Within groups	64	6541	5223	102	82
Total	65	10250	7998		

$Fx=\frac{64}{159}=0.402$ df 1/64 F at 0.05 level=4.00

$Fy=\frac{570}{126.6}=4.50$ df 1/64 F at 0.01 level=7.08

Fx is not significant
Fy is significant at 0.05 level but not at 0.01 level

(*iii*) *Analysis of Covariance*

Sources of variance	**df**	**SS_x**	**SS_y**	**S_{xy}**	**S_{yx}**	**$MS(V)_{yx}$**	**$S.D_{yx}$**
Between means	1	64	570	602	2677	2677	$\sqrt{80}$
Within groups	63	10186	8104	1089	5042	80	$=8.94$
Total	64	10250	7998	1691	7719		

$Fy.x=\frac{2677}{80}=33.46$ Highly significant at 0.01 level

F at 0.05 level=4.00 at 0.01 level=7.08

(*iv*) *Adjusted Means*

Groups	**N**	**M_x**	**M_y**	**M_{yx}**	**Adjusted**
Experimental IX-A	36	25.50	17.50	17.68	Mean Difference 6.27
Control IX-B	30	27.47	11.60	11.41	
General Means		26.49	14.55	14.55	

Significance of difference between adjusted Y means

$$A.D._{yx}=\sqrt{80}=8.94$$

$$S.EM_{yx}=\frac{8.94}{\sqrt{30}}=1.63$$

A.E$_D$ between any two adjusted means

$$S.D._{yx}\times\sqrt{\frac{1}{N1}+\frac{1}{N2}}=8.94\sqrt{\frac{1}{36}+\frac{1}{30}}=2.24$$

With df=63, t at 0.05=2.00 and at 0.01=2.66
Computed t-value at 0.05 level=2.00×2.24=4.48
At 0.01 level=2.66×2.24=5.96
Observed value 17.68—11.41=6.27

As the observed value of 6.27 is more than the computed value of 5.96 the difference in the means is significant and the null hypothesis stands rejected.

10.8 ANALYSIS OF COVARIANCE (Intelligence test, Pretest and Post-test)

H : 4 There is no significant difference between achievement means of experimental and control group, when the experimental group is taught using objective based instruction, and the two groups are equated on the two control measures (Intelligence and prior biology achievement).

Following tables 45 and 46 were used for analysis of covariance :

Table 45

DATA REGARDING CRITERION AND CONTROLS FOR ANALYSIS OF COVARIANCE

Methods of Teaching	N	CRITERION Post-test Achievement		CONTROLS Prior Achievement in Biology		Intelligence Scores	
		Σy	$\bar{y}$	Σx_1	$\bar{x}_1$	Σx_2	$\Sigma \bar{x}_2$
Objective based instruction	36	630	17.50	918	25.50	2505	69.58
Traditional instruction	30	348	11.60	824	27.47	2105	70.17
Total	66	978	29.10	1742	52.97	4610	139.75

Table 46

DATA SHOWING MEASURES RELATING TO EXPERIMENTAL, CONTROL AND ENTIRE GROUP

Measure	Symbol	Total for expt. group	Total for control group	Total for entire group
1. Criterion Achievement test (Taxonomic Post-test)	ΣY^2	16044	6446	22490
2. Prior Biology Achievement test (Pretest)	ΣX_1^2	28548	27680	56228
3. Intelligence test (V+N)	ΣX_2^2	180358	152177	332535
Cross Products				
4. Prior achievement criterion (Pretest × Post-test)	$\Sigma X_1 Y$	17204	9508	26712
5. Intelligence × Criterion (Intelligence × Post-test)	$\Sigma X_2 Y$	44884	24443	69327
6. Intelligence × Prior achievement (Intelligence × Pretest)	ΣXX_{12}	66366	60504	126870

(Table 46 Contd.)

SUM OF SQUARES OF RESIDUALS

Source of variations	Degree of freedom	Sum of squares	Mean Sq.	F
Between	1	1257.62	1257.62	11.45
Within	62	6812.25	109.88	
Total	63	8069.87	1367.50	

Since F-value of 11.45 is more than given value of 7.08 at 0.01 level, it indicates that difference between the experimental and control group as far as their achievement is concerned, is significant. It, therefore, provides conclusive evidence about the positive impact of process of teaching in development of intended learning outcomes. The null hypothesis of no difference existing due to planned and conscious objective-centred teaching is, therefore, rejected.

This evidence supports the view expressed by Dave (1972) that

> "learning is essentially a developmental process and an attempt to evaluate what is not consciously planned and in all probability might not have been developed is futile".

Stimulation of the relevant mental process with reference to a particular fact or concept or theory through appropriate classroom interaction between the teacher, student and the materials, is indeed what is required to achieve the intended learning outcomes. For this goal directedness on the part of the teacher, deliberately planned and structured learning experiences, use of objective-centred questions for formative evaluation for evoking the desired mental process, are important factors of which we should be aware of.

11

11.0 VALIDATION THROUGH COMPATIBILITY OF PRODUCT AND PROCESS RESPONSES

Most of the studies on validation of the taxonomy are based on the product responses as indicated by students in the form of correct or incorrect answers. In case of a correct product response the assumption is that the examinee has also used the corresponding mental process in attempting a particular question correctly or incorrectly. Since there could be a possibility that the mental process (process response) used by the examinee may not be the same as implied by a particular category of objectives but still may arrive at the correct response and vice-versa. If the six objectives of the taxonomy are arranged in hierarchical order, the obvious inference could be that the process response as implied by an objective must also be in consonance with the product response. Thus there has to be concurrence between process responses and the product responses of students, in case there is hierarchy in these objectives. It was, therefore, considered necessary that compatibility of process and product responses be found out in respect of all the six objectives listed in the Bloom's taxonomy. To investigate the same the following hypothesis was formulated.

TESTING OF HYPOTHESIS—5

H : 5 There is no significant difference between students who attempt an item correctly and those who do not, as far as the use of mental processes in attempting an item is concerned.

When an item is attempted by a student two types of responses are visualised according to the taxonomy. One, whether he used the appropriate mental process supposed to have been evoked by the stimulus provided in the stem of the item. This according to Kropp and Stoker (1966) may be called the 'Process Response' and is independent of the correctness or otherwise of the student's actual response. Two, whether the student gave the correct or incorrect response as a result of the process response. This is termed as 'product response' which may be the resultant outcome of the process response or may be in spite of that for various other reasons. Marshalling the relevant content and its proper manipulation with the relevant mental process leads to the product response.

11.1 IDENTIFICATION OF PROCESS RESPONSES

There are two ways of searching evidence of the validity of the taxonomic test. Firstly ; the validity of items can be judged by agreement of experts to classify the items into respective categories of objectives, a technique used in this study. Objective-wise categorisation by raters of the objective-based items prepared by constructor is a good criterion of content validity. Secondly ; evidence of validity can be searched from the students who may be prompted to tell us to how they arrived at the solution, of the items they attempted. In other words they may be asked to verbalise by identifying the mental processes (process response) which they used in attempting an item. For identification of the process response two methods can be used ; to collect verbalisations while the student is solving the items or checking a solution from a list of process responses given to him ("Laundry List" technique). For reasons already explained in Chapter VI, the laundry list technique was used in the present investigation (Annexure-D).

The two observational conditions that needed consideration were the content and format of items. Content was equalised by making every set of six items on the same concept. As for format some validity of product responses had to be sacrificed at the alter of objectivity in measurement of those responses. That is why multiple choice items rather than open-ended questions which ensure better validity of responses, were used in the test-construction.

In the present investigation Sample-C (IX-A) which formed a part of Sample-B was used to identify process responses. If assumption regarding difficulty and complexity about items testing different objectives is correct, then among the judges/raters' agreement should be the highest with respect to items on knowledge and less in order from Knowledge to Evaluation.

11.2 FREQUENCY DISTRIBUTION OF RESPONSE MEASURES

As discussed in last chapter on development and administration of the post-test students' response measures were collected for sample-C (Experimental group) which is a part of sample-B used to test hypothesis No. 4. Students process response measures were collected and tabulated according to frequency distribution of response measures on each item against each objective together with the average frequency for six objectives as shown in the Table 47 (a-f).

In each of the six Tables 47 (a-f) the top row indicating 1, 7, 13, 19, 25, 31, 37, 43, 49, 55 in the first table are the serial number of the items based on Knowledge objective. Under each item say, item No. 1, are the frequencies on each objective given column-wise, in this case, 24, 3, 01, 04, 01 and 03 respectively. Thus 24 students used mental process (as shown by their response measure) which are implied by Knowledge objective, 3 used mental process related to Comprehension, 1 to Application, 4 to Analysis, 1 to Synthesis, and 3 to Evaluation. Therefore, 36 response measures for each item were classified objective-wise. The last column indicates the average frequencies on all the 10 knowledge-based items shown against each row of objective, i.e., 20.3, 4.4, 3.5, 2.2, 2.2 and 3.9, for K, C, AP, AN, S and E respectively.

The same scheme is depicted for all the 6 objectives.

Table 47

OBJECTIVE-WISE FREQUENCY DISTRIBUTION OF RESPONSE MEASURES

(a) *Knowledge*

Item No. Objective	1	7	13	19	25	31	37	43	49	55	Average Frequency
K	24	22	27	23	15	23	14	14	25	16	20.30
C	03	07	03	02	06	03	08	01	02	09	4.4
AP	01	03	03	03	04	06	02	05	04	04	3.5
AN	04	01	00	04	01	01	03	05	01	02	2.2
S	01	01	01	02	02	03	07	04	01	00	2.2
E	03	02	02	02	08	00	02	07	03	05	3.9
Total	36	36	36	36	36	36	36	36	36	36	36.0

(b) *Comprehension*

Item No. Objective	2	8	14	20	26	32	38	44	50	56	Average Frequency
K	10	16	14	09	14	14	06	15	09	13	12.0
C	08	08	05	04	07	05	09	06	09	07	6.8
AP	05	07	06	10	06	08	10	02	11	06	7.1
AN	06	02	02	07	05	02	03	07	04	08	4.6
S	02	02	06	05	01	02	05	04	01	01	2.9
E	05	01	03	01	03	05	03	02	02	01	2.6
Total	36	36	36	36	36	36	36	36	36	36	36.0

(c) *Application*

Item No. Objective	3	9	15	21	27	33	39	45	51	57	Average Frequency
K	05	06	07	10	09	04	09	07	05	07	6.9
C	10	06	09	09	05	10	05	07	07	07	7.5
AP	11	10	08	04	10	06	12	09	14	08	9.2
AN	01	03	05	05	04	06	04	07	04	04	4.3
S	06	05	05	01	04	05	02	01	04	06	3.9
E	03	06	02	07	04	05	04	05	02	04	4.2
Total	36	36	36	36	36	36	36	36	36	36	36.0

(*d*) *Analysis*

Item No. Objective	4	10	16	22	28	34	40	46	52	58	Average Frequency
K	06	02	11	05	04	06	01	05	04	05	4.9
C	08	04	05	02	05	06	07	06	05	03	5.1
AP	11	05	07	09	06	07	06	03	06	09	6.9
AN	03	08	06	06	06	06	08	04	11	07	6.5
S	05	11	03	05	10	08	10	07	05	08	7.2
E	03	06	04	09	05	03	04	11	05	04	5.4
Total	36	36	36	36	36	36	36	36	36	36	36.0

(*e*) *Synthesis*

Item No. Objective	5	11	17	23	29	35	41	47	53	59	Average Frequency
K	01	02	07	01	01	04	04	06	04	07	3.7
C	06	05	06	04	06	10	03	07	02	08	5.8
AP	04	05	09	08	08	01	08	09	08	03	6.3
AN	13	11	07	08	07	05	07	02	07	08	7.5
S	03	06	02	06	08	08	03	05	04	03	4.8
E	08	07	05	09	06	08	11	07	11	07	7.9
Total	36	36	36	36	36	36	36	36	36	36	36.0

(*f*) *Evaluation*

Item No. Objective	6	12	18	24	30	36	42	48	54	60	Average Frequency
K	04	04	05	09	05	06	01	11	05	06	5.6
C	02	00	02	04	03	02	04	05	06	02	3.0
AP	04	09	04	03	06	07	09	07	02	05	5.6
AN	06	06	02	09	08	07	06	03	08	04	5.9
S	08	06	05	05	05	03	10	05	07	07	6.1
E	12	11	18	06	09	11	06	05	08	12	9.8
Total	36	36	36	36	36	36	36	36	36	36	36.0

11.3 OVERALL ANALYSIS OF PROCESS RESPONSES

Examination of overall picture as evident from the tables 47 (a-f) reveals that students were able to identify the relevant mental process of Knowledge very clearly (56%). Next comes the Evaluation category (27%) which emerges more clearly than the other remain categories. Application is almost close to Evaluation (26%). Picture of Analysis and Synthesis is quite confusing. Surprisingly the lowest percentage (19%) of relevance of process responses is in the case of Comprehension objective which is in fact, more complex than only Knowledge and as such should have figured out more prominently. Detailed analysis of process responses provided more evidence about each of the objectives as far as relevance of mental process used by students, is concerned.

11.4 OBJECTIVE-WISE ANALYSIS OF PROCESS RESPONSES

(i) *Knowledge* (Table 47-a)

Average score of 36 students on Knowledge objective is 20.30 and the next highest loading is 4.4 on Comprehension. This shows without any doubt that mental process of recall has been mainly responsible for this and students could identify or attempt knowledge items on the basis of related mental process. This category standsout most clearly.

(ii) *Comprehension* (Table 47-b)

In terms of identification of mental processes students have not been able to do it as the average score is only 6.8. But if we look to the average score of Knowledge (12.0) and Application (7.1) in the same column it becomes clear that students confused this objective with Knowledge on the one hand and Application on the other, both of course being adjacent categories. Predominance of Knowledge (12.0) average score reveals that students' confusion on Comprehension was more with the Knowledge objective.

(iii) *Application* (Table 47-c)

The category comes out more clearly than Comprehension. The average score (9.2) is almost next to Knowledge which shows that there is less confusion on this category and the process responses are identifiable more clearly as distinguished from the Knowledge and Comprehension on one side and Analysis and Synthesis on the other. Its (AP) greater load (7.1) on Comprehension process (Table 47-b) and Comprehension (7.5) on Application process (Table 47-c) also indicate that as far as use of mental processes is concerned Application category is quite close or adjacent to Comprehension.

(iv) *Analysis* (Table 47-d)

Its average score is 6.5 and the weightages on adjacent categories of Application (6.9) on one side and Synthesis (7.2) on the other show a very hazy picture. Students seem to have either confused such items with Application or with Synthesis in identifying the process responses. Since picture of Synthesis itself is still more confusing as discussed a little later, this category of Analysis has in no way been distinguished by students as a separate class of behaviours.

(v) *Synthesis* (Table 47-e)

This category appears to be the most confusing one. It has the lowest average score (4.8) having maximum average on Evaluation (7.9) followed by Analysis (7.5), Application (6.3), Comprehension (5.8) and Knowledge (3.7) in that order. Thus this category appears to have confused students the most. That is why the process responses on this category do not seem to follow any pattern or direction to support the claim for its independence as a mental process which could be the basis for the correct process responses.

(vi) *Evaluation* (Table 47-f)

Average score on Evaluation is the highest (9.8) among the last five categories C to E. Thus next to Knowledge, the hierarchy is more clear in case of Evaluation category. The use of relevant mental process in this case can be attributed to some component which appears unique to this category as Kropp and Stocker (1966) suggest in their hypothesised factor analysis pattern. It may be due to this less mistakable and unoverlapped mental processes implied in the Evaluation category that students' process responses correspond better to the product responses.

Thus the overall picture of the responses as shown in the six Tables (47 a-f) reveals that students can identify more easily the mental process corresponding to the product responses in case of the Knowledge, Application and Evaluation. Similar establishment of correspondence between process and product responses is not observed in case of Comprehension. The reason for this could be traced to the high average scores in case of such items on the Knowledge category. It appears that students get confused mainly due to closeness of Comprehension with Knowledge category which lead to decrease in the average score on Comprehension.

11.5 CHANCE FACTOR IN PROCESS RESPONSES

On the basis of Table (47 a-f) chi-squares were computed for each item using column or frequencies given against each objective K-E. These values of chi-squares are entered in Table 48. Out of table of 60 only, 23 chi-squares are significant while remaining 37 are non-significant. The objective-wise position of significant and non-significant values are given below :

Sl. No.	**Objective**	**K**	**C**	**AP**	**AN**	**S**	**E**	**Total**	
1.	Significant at 0.01 level	10	6	1	0	1	1	19	23
2.	Significant at 0.05 level	0	1	2	0	0	1	04	
3.	Not significant	0	3	7	10	9	8	37	
	Total	10	10	10	10	10	10	60	

Table 48

CHI-SQUARES SHOWING CHANCE FACTOR IN OVERALL IDENTIFICATION OF PROCESS RESPONSES

Item No.	K	Item No.	C	Item No.	AP	Item No.	AN	Item No.	S	Item No.	E
1.	16.00	2.	06.30	3.	12.60	4.	08.00	5.	15.50	6.	08.66
7.	11.66	8.	27.00	9.	04.33	10.	08.33	11.	07.33	12.	12.33
13.	13.22	14.	15.00	15.	06.50	16.	06.66	17.	04.66	18.	30.33
19.	16.22	20.	09.33	21.	09.33	22.	06.00	23.	08.83	24.	05.66
25.	21.66	26.	16.60	27.	06.30	28.	03.66	29.	05.66	30.	04.00
31.	16.00	32.	17.00	33.	03.50	34.	02.33	35.	10.50	36.	08.33
37.	18.33	38.	07.33	39.	11.66	40.	08.33	41.	08.66	42.	09.00
43.	16.33	44.	21.16	45.	06.33	46.	06.60	47.	04.66	48.	06.37
49.	13.33	50.	14.60	51.	15.00	52.	05.33	53.	08.66	54.	04.33
55.	21.66	56.	17.30	57.	02.30	58.	04.66	59.	04.66	60.	09.66
Significant Chi-squares											
	10		7		3		0		1		2=23

Value 0.01=15.086 0.05=11.070 df=5

Thus it is about 40% cases that we can say that the mental processes as identified by students is better than chance distribution. However, if we examine the 23 significant cases, further, the picture becomes clearer. There are 10 out of 23 values which fall in the area of Knowledge and 7 in the area of Comprehension. This means that even out of this percentage (40%) more than 70% (17 out of 23) cases are among the lower categories, Knowledge itself taking away a big chunk (10) of about 50%. This means that distinction is possible only at the lower level of hierarchy which involves simpler mental processes as compared to other categories of more complex nature. Thus significance of difference in 23 cases is by and large (17 out of 23) limited to the two lower most categories of objectives. Out of the remaining 6 cases, 3 are from the area of Application, 1 from Synthesis and 2 from Evaluation. Even in case of Synthesis it is not real, in the sense that it is due to confusion with Analysis which has high weightage in this case (item

No. 5). In the remaining five, 3 from Application and two from area of Evaluation, significance is due to the clear identification of the relevant mental processes involved in these categories. Thus if Synthesis is not accounted for, it is only 5 items whose significance is without any doubt. If 10 cases of Knowledge which involves simple recall or remembering process and identifiable without much difficulty, is not considered it is not more than 12 items, i.e., 20% of the total, where significance of product responses can be attributed to the corresponding process responses vis-à-vis the right mental processes.

In case of 37 items where difference is not significant, when coupled with 10 items from Knowledge area, do form at least three-fourth majority of items where picture is almost confused. On the whole, therefore, mental processes *have not been identified better than chance.* In all these items use of wrong mental processes can be attributed to the intriguing behaviour of the objectives like Analysis and Synthesis which seem to have involved mental processes which are either not independent from or form a part of those mental processes which are attributable to Application objective or to Evaluation category.

Since the objectives from Comprehension onward overlap more and become increasingly complex it is quite possible that students too become confused to isolate the right mental process from the wrong mental process within the over-riding jurisdiction of those objectives. Evaluation being the end-of-the-ladder category, seems to permit better identification of right mental process because of one or more of the mental processes peculiar to it but not overlapped by any other mental process as is the case in all the other categories ranging from Comprehension to Synthesis.

Whatever the reasons be, the data seem to support appreciably the null hypothesis of no difference existing in the use of mental processes, between those students who attempt an item correctly and those who do not. The hypothesis, therefore, cannot be rejected and remains tenable in this case.

11.6 RELATIONSHIP BETWEEN PROCESS RESPONSES AND PRODUCT RESPONSES

After determining the overall position of the process responses, indicative of mental processes on different objectives, next attempt was made to see whether the correct product responses (Keyed answers) are due to the exercise of the right mental process or irrespective of them. For this the following analysis was done for each question :

- (i) Classifying students into two groups viz., those attempting the item correctly (R) and those who attempted them wrongly (W).
- (ii) Dividing further each group into those who identified the correct mental process, i.e., (RR) and (RW) and those failing to do so, i.e., (WR) and (WW). This gave rise to the following 2×2 contingency table in case of each item.

Response to questions

Identification of mental processes	R	W
R	RR	WR
W	RW	WW

(ii) Chi-squares were calculated for all the 60 items. Objective-wise significant and non-significant values as computed from the 60 contingency tables prepared for this purpose are given below :

Sl. No.	Objectives Level of significance	K	C	AP	AN	S	E		Total
1.	0.01	1	1	0	0	1	1	4	11
2.	0.05	1	2	2	1	1	0	7	
3.	Not significant	8	7	8	9	8	9		49
	Total	10	10	10	10	10	10		60

From the following table it is observed that only in case of 11 items out of 60 the chisquare values are significant whereas the remaining 49 are non-significant. Table 49 gives the details of chi-square values under each objective K to E. From this table out of 11 significant values two Items No. 13 and 55 are from K, three (6, 26, 56) from C, two (15, 45) from AP, one from AN (28), two (35, 53) from S and one (42) from E. It can be inferred from this that identification of right-wrong mental processes is slightly easier in the first three categories which have 7 out of 11 significant chi-square.

In other words the mental processes involved in solving questions on K and C are more clearly differentiated by students than those involved in the remaining categories AP, AN, S and E which are claimed in taxonomy, to be more and more complex.

Table 49

CHI-SQUARES SHOWING GROUPWISE SIGNIFICANCE OF DIFFERENCE IDENTIFICATION OF MENTAL PROCESSES

Sl. No.	K		C		AP		AN		S		E
1.	0.026	2.	*6.181	3.	0.069	4.	1.440	5.	0.403	6.	2.095
7.	0.719	8.	2.667	9.	0.361	10.	0.088	11.	2.250	12.	0.234
13.	*3.896	14.	0.116	15.	*5.644	16.	0.000	17.	1.348	18.	0.528
19.	0.602	20.	0.726	21.	1.406	22.	0.122	23.	0.206	24.	0.206
25.	1.685	26.	*5.707	27.	0.600	28.	*4.425	29.	1.177	30.	0.049
31.	0.890	32.	0.380	33.	0.697	34.	2.322	35.	*8.348	36.	0.000
37.	2.258	38.	0.148	39.	1.148	40.	2.141	41.	2.678	42.	*8.229
43.	1.461	44.	0.093	45.	*4.615	46.	1.837	47.	1.121	48.	0.726
49.	2.363	50.	2.571	51.	0.361	52.	0.056	53.	*4.500	54.	0.000
55.	*13.166	56.	*5.994	57.	0.857	58.	0.170	59.	0.234	60.	0.000
			df=1		0.05=3.841				0.01=6.635		

Significant Chi-squares (*)	K	C	AP	AN	S	E	Total
Item No.	13,55	2,26,56	15,45	28	35,53	42=11	
Total	2	3	2	1	2	1=11	

df=1 .05=3.841
.01=6.635

Nevertheless, the number of significant values is even less than 20% (11 out of 60) the question of rejecting the null hypothesis does not arise. On the contrary it provides good evidence of no difference existing between students who attempt an item correctly and those who fail to do it as far as the exercise of mental processes is concerned. The hypothesis thus formulated is sustained.

11.7 TWO BASIS OF COMPARISON OF SIGNIFICANT AND NON-SIGNIFICANT ITEMS

When Tables 48 and 49 are compared we can categorise the items into four types. Under the overall basis the items may be significant and non-significant. Likewise there may be significant and non-significant items under the category of identification of mental processes on right-wrong basis. The following Table 50 indicates the item-wise distribution relating to the four possible categories (A-D) listed under the two bases of classification.

Table 50

ITEM-WISE DISTRIBUTION OF ITEMS UNDER FOUR CATEGORIES ON USE OF MENTAL PROCESSES

Category	Significance of difference on overall basis I	Item-wise distribution in each category A to D	Total items in each case	Significance of difference on Right-Wrong basis II
A	Significant	13, 26, 55, 56	04	Significant
B	Significant	1, 3, 5, 7, 8, 12, 14, 18, 19, 25, 31, 32, 37, 39, 43, 44, 49 50, 51	19 } 27	Not significant
C	Not significant	2, 15, 28, 35, 42, 45 53, 58	08	Significant
D	Not significant	4, 6, 9, 10, 11, 16, 17, 20, 21, 22, 23, 24, 27, 29, 30, 33, 34, 36, 38, 40, 41, 46, 47, 48, 52, 54, 57, 59, 60.	29	Not significant

Table 50 shows that there are only four items which show significant values on both the aspects I and II. As for Categories B and C the figures 19 and 8 respectively make a total of 27. As compared to figure of 29 in Category D the combined figure of 27 for B and C is hardly meaningful from the point of view of significance because 50% of items (29 out of 60) are clearly non-significant. When taken together it is hardly 60% (4 items) of the cases that show significant differences. The overall picture is, therefore, very disappointing. Number of 56 non-significant values out of 60 on the overall performance for identification of relevant mental processes gives a clear verdict in favour of the null hypothesis which remains tenable in this case.

11.8 STUDENT VERSUS EXPERT-GENERATED HIERARCHY

In the present study every set of item was based on the same concept thereby providing the same stimulus for all the 6 items. In spite of that the variation in the correctness of product responses is observable. This should be due to unfamiliarity of the situation which goes on increasing from Knowledge to Evaluation. This unfamiliarity requires the students to use more complex mental processes to arrive at the correct product response. This may be due to diffusion of more and more mental processes which cause disagreement among the students on process responses.

Similar difficulty seems to have been encountered by evaluators/raters who classified the first draft of 144 items into different categories of objectives. Analysis of frequency distribution of raters' agreement reveal almost similar pattern. The 22 raters who classified the items had a great divergence of opinion. The average agreement on different objectives was 17.63 on Knowledge, 8.42 on Comprehension, 6.16 on Application, 7.0 on Analysis, 6.42 on Synthesis and 8.89 on Evaluation. In case of Comprehension most raters classified these items into Knowledge category. If such frequencies are added to this category the agreement average rises from 8.42 to 15.62. Here again a little higher agreement in case of Evaluation items is noticed. The indistinguishable difference in Application, Analysis and Synthesis categories can be explained by same logic as in case of student generated hierarchy discussed earlier. In both cases evidence appears to complement each other. Nevertheless, data are too meagre to draw any definitive conclusions. Further evidence is warranted.

The results of this study as emerged from the testing of various hypotheses can now be summarised in the form of findings and conclusions on the basis of which implications for various components of the educational processes can be worked out. This would also help in exploring allied areas of research. The possibilities are discussed in the last chapter that follows.

12

12.0 FINDINGS, CONCLUSIONS AND IMPLICATIONS

The preceding chapter on statistical analysis and interpretation has provided a lot of evidence about the various postulates of the taxonomy of educational objectives by Bloom and his associates. The evidence that accrued from the analysis of the data can now be summarised in the form of final conclusions and findings which in turn can lead to the tracing of various implications of this study for further research and for improving the curriculum and the teaching learning process. Each of these aspects is delineated below within the parameters of present investigation.

12.1 FINDINGS

These can be listed with reference to each of the three postulates which formed the basis of the formulation of the hypotheses.

12.1.1. HIERARCHY IN TAXONOMY

(i) Graphical curves of frequency polygons for the distribution of objective-wise scores show hierarchical trends from 'Knowledge' to 'Evaluation' in general but for the inconsistent behaviour of the 'Analysis' category in Class IX and 'Synthesis' in all the three Classes from IX to XI.

On the basis of the significance of difference in the means of different objectives the following are the main findings.

(ii) 'Knowledge' is at the lowest rung of the taxonomic ladder of objectives while 'Evaluation' tops the hierarchy.

(iii) The hierarchy is clear in the first three objectives, Knowledge to Application followed by Evaluation, thereby indicating the position as $E > AP > C > K$.

(iv) In case of Analysis and Synthesis the hierarchy is not clear. Analysis seems to merge with Application while Synthesis has functioned only at a level comparable to Comprehension, thereby losing claim for their independent existence as separate categories. It is apprehended that this position may be due to format of items on Synthesis which if tested through open-ended questions, might provide evidence different from the one now accrued by use of multiple choice items. This needs further investigation.

(v) The apparent marked distance between Evaluation and Synthesis is indeed due to Synthesis having obtained in the much lower level hierarchy of Synthesis (down graded to Comprehension level) as we see in case of Comprehension with Evaluation.

(vi) On the basis of bivariate joint distribution of scores on different pairs of objectives the position is almost similar. However, Synthesis appears to be slightly higher than Comprehension which in turn seems to overlap with Knowledge quite a bit.

(vii) Synthesis occupies a lower level than Analysis in the hierarchy while the latter overlaps Application to such an extent that it appears to be merging with it.

12.1.2 CUMULATIVENESS OF THE TAXONOMY

About cumulative hierarchy the evidence is of mixed nature.

(i) Shape of graphical curves, analysis of frequency distribution of scores in terms of high and low ranges of scores and objective-wise cumulative scores, all indicate clear cumulative hierarchy from Knowledge to Application.

(ii) Synthesis is quite out of place and has behaved just like a complement to Comprehension, rather than acting as an objective higher in order than Application and Analysis.

Position of analysis is quite intriguing. It seems to be subservient to both Application and Evaluation. It appears to be either an integral part of these objectives or a pre-requisite to the development of both.

(iii) Evaluation category appears to be pitched at the top of hierarchy although the distance between this and the Application category is not that apart as it is seen, among the first three categories.

(iv) Guttman's Simplex analysis does not provide clear-cut picture of the simplical structure. In general the Radex technique shows quasi-simplical structure which supports more clearly the cumulative hierarchy in case of Knowledge, Comprehension and Application. Position of Analysis and Synthesis, especially the Synthesis disturbs the simplex more often than not. Evaluation, however, appears as a top level category in the hierarchy.

(v) Factor Analysis does not support the hypothesised structure of one general factor, four group factors, and one unique factor. Only one factor which may be called a general factor is prominent as is evident by the high loadings on all the six variables. There is some evidence of the possibility of the existence of a second factor as evident from the significant loadings on Knowledge, Application, Synthesis and Evaluation.

(vi) From McQuitty's Syndrome Analysis two patterns have emerged. In one case the syndrome is made up of the hierarchical associations representing the sequences K-S-A-C-N-E while in the other it is K-S-N-C-A-E. This shows that position of Knowledge, Synthesis and Evaluation remains the same. The combined merged syndrome is like $K \rightarrow S \rightarrow (N\text{-}C\text{-}A) \rightarrow E$.

12.1.3 COGNITIVE PROCESS AS LEARNED BEHAVIOURS

(i) Significant difference exists in students' achievement not only in terms of overall performance with respect to each class but also with respect to each objective. The same is true even in terms of school-wise performance, thereby supporting the claim that cognitive behaviours designated in the taxonomy are learned behaviours.

K—Knowledge
N—Analysis
C—Comprehension
S—Synthesis
A—Application
E—Evaluation

12.1.4 IMPACT OF OBJECTIVE-BASED TEACHING

(i) Objective-based instruction involving various levels of interaction for developing different abilities as implied by different objectives, does improve student's learning with respect to Comprehension, Application and Synthesis (synthesis/comprehension).

(ii) Since no appreciable interaction between teacher and student is involved while teaching for Knowledge objective, the objective-based and traditional teaching make little difference because of the use of the major process of 'remembering' or 'recall' implied in Knowledge objective.

(iii) Lack of significant difference in case of Evaluation, as a result of objective-based instruction can be attributed to the need for more time required for developing this ability.

(iv) Objective-based instruction made a significant difference in the development of ability to comprehend and to apply, with regard to high achievers of experimental group when compared with their counterparts in control group.

(v) Objective-based instruction made a significant difference in achievement on Comprehension objective, between the low achievers of the experimental and control groups.

12.1.5 RELATIONSHIP BETWEEN PROCESS-RESPONSES AND PRODUCT-RESPONSES

(i) Students can identify the mental processes corresponding to the product responses more easily in case of Knowledge, Application and Evaluation and not in case of Comprehension, Analysis and Synthesis. Difficulty in identifying C from K may be due to overlap which is prominent in the distribution of scores while the inconsistent behaviour of Analysis and Synthesis itself might be causing difficulty in identifying related mental processes.

(ii) There is no significant difference between students who attempt an item correctly and those who fail to do it as far as the use of the mental processes is concerned.

(iii) Similar pattern of student-generated hierarchy is observable as in the case of expert generated hierarchy although data are too meagre to draw any definite conclusion.

12.2 CONCLUSIONS

(i) Out of the three postulates of Bloom's taxonomy taken up in this study, the one related to the cognitive behaviours as learned behaviours is clearly demonstrated. Class-wise, objective-wise and even school-wise data fully support that the cognitive behaviours stipulated in the taxonomy are learnt behaviours.

(ii) Hierarchy of objectives as claimed by Bloom is not demonstrated. But for the position of Knowledge and Evaluation categories, the position of other categories is not that distinct. Nevertheless, the hierarchy in the first three objectives, Knowledge, Comprehension and Application is demonstrated. Therefore, the 4-tier and not the 6-tier hierarchy is observed representing the sequence K→C→AP→E.

(iii) When cumulativeness of the hierarchy is judged, the evidence is quite different as revealed through McQuitty's Syndrome Analysis. The cumulative hierarchy is like K→S→(C.N.AP)→E relegating Synthesis to the level below even Comprehension and close to Knowledge. Similar picture emerged from student generated hierarchy. Thus the evidence supports the view of the taxonomy that learning is cumulative but order of cumulative learning is not substantiated.

(iv) Hierarchical position of Analysis and Synthesis seems to support the 3-tier taxonomy used and advocated by the National Council of Educational Research and Training, according to which Analysis and Synthesis are included under the category of Application. However, Evaluation which is neither represented as a separate category nor as a part of Application, has a claim for its independent existence thus making it as a 4-tier taxonomy.

(v) Place of objective based instructional material and objective centered teaching has demonstrated its positive impact on students' learning on Comprehension and Application objectives. A case for introduction of objective-based teaching can be made after further trial on a wider sample of students, in support of process-oriented approach of validation.

(vi) Correspondence between process-responses and product-responses is not demonstrated in this study. One of the potent reason that can be attributed to it is that process used by students in solving a question to arrive at its solution, is difficult for them to verbalise. Need for some alternative method of identifying the mental processes used by students in solving a question, cannot be overemphasised.

12.3 IMPLICATIONS OF THE PRESENT STUDY

The present study has a number of implications which if properly appreciated can go a long-way in appraising the existing position relating to various components of the educational process and provide the much needed basis for its vitalisation, improvement and renewal. For the sake of greater clarity and convenience these implications as discussed under the various heads like curriculum planning, standard setting, vitalising instruction, classroom testing, development of resource material, preservice education of teachers, orientation and training of teachers, administrative efficiency and future research possibilities. Each of these aspects is briefly discussed below :

(i) *Cognizance of a theoretical framework for curriculum development*

At present curriculum development activity in India lacks direction due to the absence of any theoretical framework. Need for relating curriculum development efforts to basic assumptions underlying teaching, learning and the discipline has yet to be realised by curriculum developers in general and teachers in particular. Non-cognizance of the place of objectives in curriculum development has made it difficult for curriculum workers to see eye to eye regarding effectiveness of different strategies and styles of curriculum development besides curriculum evaluation.

The present study reveals that hierarchy as alleged in Bloom's Taxonomy holds good only for knowledge, comprehension and application and to some extent evaluation. These four objectives, therefore, form the foci of curriculum planning. Once the abilities under each of these objectives are also validated (not done in the present study) the four major objectives can form the vertical as well as horizontal spectrum of the framework of objectives.

(ii) *Setting and maintaining standards*

Standards are nothing but the level of expected achievement in terms of knowledge and intellectual skills as far as the cognitive domain is concerned. The objective as emerging from this study demand respecification from the point of view of operational definition of each objective. Apart from the vertical dimension, reallocation of specific behaviours under the four objectives would also be necessitated. Standards can now be projected in terms of intended learning outcomes identified as knowledge, comprehension, application and evaluation which become the curriculum goals. Once these goals are readapted or readjusted they become the foci of teaching learning process and can be used to maintain standards of pupil's achievement. In addition the new taxonomy emerged can be used to compare standards of achievement in different states and of different institutions.

(iii) *Revitalisation of instructional practices*

The present study has clearly demonstrated the positive impact of objective-based instruction on students' achievement. The effectiveness is tangible on achievement of high as well as low achievers. The rationale followed in developing instructional plans and teaching can be used in improving instruction by using objective-based technique. Use of questions at a level beyond memory, ensuring pupil dominated classroom interaction and making students aware of intended learning outcomes, encouraging students to pose questions at higher levels etc. can be made use of in improving teaching and learning. Depending upon the intended learning outcomes the strategy of teaching can be adapted.

(iv) *Criterion-referenced testing*

Since the emphasis on objective-based instruction is recommended, testing has also to be objective based. Judging by group averages will have to be replaced by the criterion of objectives of the unit of teaching. Testing for mastery of objectives of instruction and maximum attainment level will be the aim of teaching and testing. But this is possible only when the process and product of learning go hand in hand. Teaching has to act as criterion behaviour for evaluation of pupils. Unless a product, i.e., knowledge, skills and abilities, is purposefully developed through teaching, it might not have developed and as such cannot be tested. Therefore, the most cogent approach will be to conceptualise the process in accordance with the expected or intended learning outcomes. The study highlights the importance of formative evaluation where testing becomes an integral part of teaching and a continuous process of appraisal and feedback. Test planning and analysis will be geared to the instructional objectives whereby objective or criterion referenced testing would replace norm reference testing. Criterion behaviour will be determined by the scope of each of the objectives of the Taxonomy. Thus test planning can now be taken up more logically as the rationale is provided by the observed hierarchy and cumulativeness.

(v) *Development of curricula at different levels*

This study has revealed the complexity of each objective as well as the relationship among the objectives. When each of the objectives is further validated in terms of its specific behaviours or learning outcomes, it provides the needed extensiveness and the intensiveness of each objective. Depending upon the extent to which each objective is to emphasised at each level the curricula at various levels can be developed. The same logic can also apply to the construction of ordinary and advance level syllabi for a particular class.

(vi) *Reorganisation of learning experiences*

Cumulative hierarchy as observed K→C→AP→E provides a basis for planning and organisation of learning experiences. Selection and sequencing of learning experiences will be facilitated in conformity with the complexity and hierarchical arrangement of objectives. Likewise, instruction can be geared to the development of various mental processes as implied by different objectives. Reorganisation of curricular experiences on the basis of new taxonomy would ensure good articulation of syllabus.

(vii) *Development of resource material*

One of the important implications of this study is for the development of various types of instructional, evaluation and self-learning materials. Based on the taxonomic order of objectives and the scope of each objective, tools and techniques of evaluation can be categorised in accordance with the complexity of the mental processes involved. Development of question banks at the level of Boards of Secondary Education, institutions and subject teacher would find a more logical basis for categorisation of items, unit tests, diagnostic tests, sample question papers and item cards. Similarly development, classification and appraisal of unit plans, teaching units, resource units and teaching modules can be done on a sounder basis in accordance with the different categories of objectives.

(viii) *For better diagnosis and remediation*

The taxonomical objectives would provide basis for discriminating students at various levels if the test batteries developed on all the taxonomic objectives are used after every unit of teaching. This will be further useful if sub-classes under each objective are also validated. Once the teachers classify students according to various levels of their achievement in terms of specified objectives, diagnosis of students' weaknesses is facilitated as also the remedial work. Sequencing the remedial teaching, teaching according to complexity of the mental processes as implied in the taxonomic objectives, become more scientific or logical.

(ix) *A framework for examining agencies*

Boards of Secondary Education, Directorate of Education, and such other agencies which are engaged in designing question papers, analysis of results and their interpretation and promotion policies can make use of taxonomic tests profitably. Depending upon the weightages given to various objectives in the hierarchy standards of achievement can be projected, maintained and compared. Existing tests can be reviewed and reclassified. A balance between lower level and higher level objectives can be maintained in setting question papers. Standardisation of tests will now be more in terms of objectives rather than in terms of content. For selection of candidates for admissions and award of merit scholarships tests based on higher level of taxonomic objectives like Application and Evaluation can be used with profit.

(x) *Use in Selection tests*

The four tier taxonomy emerged in this study by and large represents the objectives in order of Knowledge, Comprehension, Application and Evaluation. Since these objectives are arranged in increasing order of their complexity of the mental processes implied in each of these objectives of the taxonomy, advantage can be taken of to discriminate students at different levels by setting questions on selected objectives. Therefore, for selection tests which aim at discriminating students at higer level, the examining agencies can set questions mostly based on Application and Evaluation objectives. That would facilitate in discriminating bright students to be selected for admission to courses for higher learning, jobs in various professions and for award of scholarships.

(xi) *Basis for reducing curriculum load*

Curriculum load in a subject is basically a function of curriculum content and objectives and both can be viewed in terms of their scope and depth. Teaching learning methodology, the time stipulated for the attainment of expected level of achievement and the facilities provided are other variables which made the curriculum load heavy or light. The most cogent component is that of objective which sets limits to all other factors. In a norm-referenced traditional testing the expected level of achievement is 33% which is the qualifying work for promotion to next grade. This means that methodology of teaching can be geared to bear one-third of the total curriculum load. On the other hand the advocated criterion-referenced testing requires expected level of achievement which cannot be less than 80%. Thus the intended learning is representing instructional objectives categorised as Knowledge to Evaluation. Especially for the general education course as envisaged in the 10 years curriculum approach paper of the National Council of Educational Research and Training (1975) if development of intellectual skills rather than a particularly prescribed content, is made the focus which is quite relevant to the philosophy of general education for all, the curriculum content and its magnitude can be chiselled out in a more objective manner to bring it to the desired level keeping in view the time and other limiting factors.

(xii) *Implications for teacher education*

a. *Pre-service education* : One of the immediate needs would be to improve curriculum of teacher education colleges to incorporate the relevant methodology of teaching. As revealed in this study the process oriented evaluation of product of learning can be emphasised. The objectives of instruction in terms of K, C, AP and E can be restated and defined in operational terms. Teaching methods normally prescribed in syllabi of teachers' colleges have to be reviewed and substituted by such methods which emphasise different levels of student teacher interaction. Such methods would vary from teacher directed activities to self-learning by students corresponding to the attainment of simple objective like 'Knowledge' to that of most complex 'Evaluation'. For practice of teaching special emphasis on announcement of expected learning outcomes, objective based teaching-learning activities and use of questions at the levels of comprehension, application, evaluation etc. has to be given. Therefore, correspondence between objective-based teaching and objective-based testing has to be stressed in theory as well as practice.

b. *In-service education* : This taxonomy can go a long way in the orientation of teachers in various areas of pedagogy and content. Once we accept the cumulative hierarchy of the objectives identified as K, C, AP, AN and E its relationship with various components can be established and highlighted in orientation programmes. How taxonomy of objectives becomes the frame of reference for curriculum development, instruction and evaluation need be emphasised. Place of different objectives in the taxonomy can be discussed in such programmes, in relation to development of yearly plans, unit plans, teaching units, and instructional interventions. Likewise the role of different objectives can be explained with regard to construction of test material, classification of test items, development of item bank, tryout of questions, analysis of results, interpretation of scores, diagnosis of pupils' difficulties, testing for mastery learning etc. Thus almost all important aspects of teaching and testing can be explained in the light of nature and scope of each objective.

(xiii) *For taking administrative decisions*

Such a taxonomy can be made use of in taking a number of administrative decisions. At the level of the various Boards of examinations level, this can be used for reviewing questions papers, comparing standards of different boards, reclassification of test materials, development of question banks, for development, evaluation and renewal of curricula. At the school level decisions can be based on this with regard to judging of expected levels of achievement for promotion purposes, streaming of students for allocation of subjects, for remedial instruction, and for adapting or adopting new methods of teaching. Besides, the taxonomic objectives can also be made the basis of undertaking related programme evaluation which may lead to the changes in the objectives, curriculum, teaching-learning strategies and performance assessment procedures.

12.4 SUGGESTIONS FOR FURTHER RESEARCH

(i) The immediate need is to validate the sub-categories of the taxonomy as given under Bloom's 6-tier objectives. This might throw light on the hierarchy of the various sub-categories as also the scope of each. The results of such a study can be compared with the hierarchy worked out by Dave (1976) with respect to Knowledge, Understanding, and Application.

(ii) The present study has relevance to the 3-tier (K-C-AP) taxonomy of educational objectives being used in the National Council of Educational Research and Training. This taxonomy includes analysis and synthesis under Application objective. This needs to be verified especially with regard to the position of Analysis, Synthesis and Evaluation.

(iii) Relevance of the hierarchy of objectives to the different intellectual levels can also be found out to see if there is any relationship between the two. Which of the categories correspond more nearly to the levels of intelligence need be seen.

(iv) Higher level taxonomy tests relating to objectives like Application, Analysis and Evaluation may be validated against the creativity tests, like those of Guilford and those prepared in India.

(v) Another important area is the objective-based teaching where further research is needed to determine the mode of interaction in the classroom corresponding to attainment of various objectives in the hierarchy by students of different levels of mental functioning. This would throw more light on the relationship between the process oriented and product oriented approach of validating the taxonomy. What are the techniques of teaching which promote better learning identified as higher objective in the taxonomy need investigation.

(vi) Since very little data were used in identification of mental processes used by students to arrive at the correct responses, there is need for more elaborate efforts to establish the relationships between the students-generated and expert-generated hierarchy.

(vii) Keeping in view the data that accrued in the present study, there is need for further research to find the hierarchical relationship between K and C, AP and AN and between AN and S which do not clearly project the hierarchy as we see in the case of Knowledge and Evaluation.

(viii) It may be interesting to work out concept-wise hierarchy keeping in view the content of the various units, which may be worked out on the basis of Gagne's (1967) hierarchy and compared with the objective-wise hierarchy followed in present study.

(ix) One doubt that arises about the behaviour of the synthesis is its item format. It may be possible that the down grading of Synthesis to the level of Comprehension may be due to an artifact of the test rather than the evidence about its hierarchy. If the same questions used for Synthesis may be reframed in an open-ended form in place of the multiple-choice variety used in the present investigation, it is possible that the Synthesis category may emerge at a different level.

(x) Similar type of investigations, especially involving the relationship of the process of performance and the product of performance, may be undertaken and the relationship between process-responses and product-responses may be identified with reference to this taxonomy and in case of taxonomies other than Bloom's Taxonomy in the Cognitive Domain.

APPENDIX—A

REFERENCE NOTE FOR USE OF THE RATERS*

On some evidence available in the literature of the research on this topic, this note has been developed. It is believed that mastering this note would help you to take quick and appropriate decisions about test items and consequently it will also ensure high uniformity and reliability of the judgements taken by several judges independently. Frequent reference to the note and sample items if and when doubts arise will be very helpful. It is requested that the 144 items given be identified according to Bloom's Taxonomy of Educational Objectives and classified accordingly.

BLOOM'S CATEGORIES

According to Bloom, test items can be analysed into six different and hierarchical categories.

1. Knowledge (K)
2. Comprehension (C)
3. Application (AP)
4. Analysis (AN)
5. Synthesis (S)
6. Evaluation (E)

Instead of explaining, clarifying, or elaborating these categories only explanations are given in abridged form based on Bloom's Taxonomy of Educational Objectives : Cognitive Domain.

1.0 KNOWLEDGE

Knowledge as defined here involves the recall of specifics and universals, the recall of methods and processes, or the recall of pattern structure or setting. For measurement purposes, the recall situation involves little more than bringing to mind the appropriate material. Although some alternation of the material may be required, this is a relatively minor part of the tasks. The knowledge objective emphasise most the psychological process of remembering. The process of relating is also involved in that a knowledge test situation requires the organisation and reorganisation of a problem such that it will furnish the appropriate signals and cues for the information and knowledge the individual possesses. To use an analogy, if one thinks of the mind as a file, the problem in a knowledge test situation is that of finding in the problem or task the appropriate signals, cues, and clues which will most effectively bring out whatever knowledge is filed or stored. Thus, it may be recall of

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* Adapted from P. N. Dave's note (1973) and Bloom's Taxonomy of Educational Objectives (1956)

Specifics, Terminology, Specific Facts, Ways and Means of dealing with Specifics, Conventions, Trends and Sequences. Classifications and Categories, Criteria Methodology, Universals and Abstractions in a field, Principles and Generalisations and Theories and Structures. Broadly speaking, knowledge of specifics, knowledge of ways and means dealing with specifics and knowledge of universals and abstractions are the three major areas given under this category.

2.0 COMPREHENSION

This represents the lowest level of the intellectual skills given in this taxonomy. It refers to a type of understanding or comprehension such that the individual knows that is being communicated and can make use of the material or idea being communicated without necessarily relating it to other material or seeing its fullest implications.

2.1 TRANSLATION

Comprehension as evidenced by the care and accuracy with which the communication is paraphrased or rendered from one language or form of communication to another. Translation is judged on the basis of faithfulness and accuracy, that is, on the extent to which the material in the original communication is preserved although the form of the communication has been altered.

2.2 INTERPRETATION

It involves explanation or summarization or recognition of essentials of communication. Whereas translation involves an objective part-for-part rendering of a communication, interpretation involves a recordering, rearrangement, or to secure total view of the communication.

2.3 EXTRAPOLATION

It involves extension of trends or tendencies beyond the given data to determine implications, consequences, corollaries, effects, etc., which are in accordance with the conditions described in the original communication.

3.0 APPLICATION

The use of abstractions in particular and concrete situations. The abstractions may be in the form of general ideas, rules of procedures, or generalised methods. The abstractions may also be technical principles, ideas and theories which must be remembered and applied.

4.0 ANALYSIS

The breakdown of a communication into its constituent elements or parts such that the relative hierarchy of ideas is made clear and/or the relations between the ideas expressed are made explicit. Such analyses are intended to clarify the communication to indicate how the communication is organised, and the way in which it manages to convey its effects as well as its basis and arrangement. Analysis involves :

4.1 ANALYSIS OF ELEMENTS

Identification of the elements included in a communication.

4.2 ANALYSIS OF RELATIONSHIPS

The connections and interactions between elements and parts of a communication.

4.3 ANALYSIS OF ORGANISATIONAL PRINCIPLES

The organisation, systematic arrangement and structure which hold the communication together. This includes the 'explicit' as well as the 'implicit' structure. It includes the bases necessary for arrangement, and the mechanics which make the communication a unit.

5.0 SYNTHESIS

The putting together of elements and parts so as to form a whole. This involves the process of working with pieces, parts, elements, etc., and arranging and combining them in such a way as to constitute a pattern or structure not clearly there before.

5.1 PRODUCTION OF A UNIQUE COMMUNICATION

The development of a communication in which the writer or speaker attempts to convey ideas, feelings, and/or experiences to others.

5.2 PRODUCTION OF PLAN OR PROPOSED SET OF OPERATIONS

The development of a plan of work or the proposal of plan of operations. The plan would satisfy requirements of the task which may be given to the student or which he may develop for himself.

5.3 DERIVATION OF A SET OF ABSTRACT RELATIONS

The development of a set of abstract relations either to classify or explain particular data or phenomena, or the deduction of propositions and relations from a set of basic propositions or symbolic representations.

6.0 EVALUATION

Judgments about the value of material and methods for given purposes. Quantitative and qualitative judgements about the extent to which material and methods satisfy criteria. Use of a standard of appraisal. The criteria may be those determined by the student or those which are given to them.

6.1 JUDGMENTS IN TERMS OF INTERNAL EVIDENCE

Evaluation of the Accuracy of a communication from such evidence as logical accuracy, consistency, and other internal criteria.

6.2 JUDGMENTS IN TERMS OF EXTERNAL CRITERIA

Evaluation of material with reference to selected or remembered criteria.

SPECIMEN QUESTIONS*

1.0 KNOWLEDGE

1.1 KNOWLEDGE OF TERMINOLOGY

1. Spaniel is a type of

A. sword.
B. dog.
C. lace.
D. horse.
E. coin.

1.2 KNOWLEDGE OF SPECIFIC FACTS

2. What is the name of the process by means of which gases enter the walls of cells, are used by cells, and then leave the organism ?

A. Absorption
B. Breathing
C. Excretion
D. Expiration
E. Respiration

1.3 KNOWLEDGE OF CONVENTIONS

3. Magnetic poles are usually named

A. plus and minus.
B. red and blue.
C. east and west.
D. north and south.
E. anode and cathode.

1.4 KNOWLEDGE OF TRENDS AND SEQUENCES

4. The stages in the life history of the housefly are in order

A. larva — egg — pupa — adult
B. pupa — larva — egg — adult
C. pupa — egg — larva — adult
D. egg — larva — adult — pupa
E. egg — larva — pupa — adult

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* *Sources*

These sample test items have been drawn or adapted from the following sources :

1. Bloom, Benjamin S. *et al.* 1956. Taxonomy of Educational Objectives, Handbook 1. Cognitive Domain. David KcKay Company, Inc., New York.
2. Hedges, W. D. 1966. Testing and Evaluation for the Sciences. Wordsworth Publishing Company, Belmount, California.
3. C. U. E. B. S. 1967. Testing and Evaluation in Biological Sciences. Report of the panel on Evaluation and Testing. Publication No. 20. Commission on Under-Graduate Education in Biological Science, 1717, Massachusetts Avenue, N. W. Washington.
4. B. S. C. S. 1966-68. Test Booklet for High School Biology Experimental Materials for use. The Regents of the University of Colorado, Boulder, Colorado, USA.

1.5 KNOWLEDGE OF CLASSIFICATION AND CATEGORIES

5. The branch of biological science which deals with the structure of living organisms is called

   A. physiology.
   B. pathology.
   C. ecology.
   D. anatomy.
   E. embryology.

1.6 KNOWLEDGE OF CRITERIA

6. The criterion Darwin uses to distinguish the more variable species from the less variables species in Chapter II is

   A. number of individuals in the species.
   B. frequency of individual differences in the species.
   C. number of varies in the species.
   D. number of closely related species.
   E. number of different climatic conditions tolerated by the species.

1.7 KNOWLEDGE OF METHODOLOGY

7. When the scientist is confronted with a problem, his first step toward solving it should usually be to

   A. construct or purchase equipment.
   B. perform an experiment.
   C. draw conclusions.
   D. urge other scientists to cooperate with him in working it out.
   E. gather all available information on the subject.

1.8 KNOWLEDGE OF PRINCIPLES AND GENERALISATION

8. If the volume of a given mass of gas is kept constant, the pressure may be diminished by

   A. reducing the temperature.
   B. raising the temperature.
   C. adding heat.
   D. decreasing the density.
   E. increasing the density.

1.9 KNOWLEDGE OF THEORIES AND STRUCTURES

9. Directions : Items 60-62 (from test pool C. U. E. B. S.) are concerned with possible evidences in support of the theory of biological evolution. Select from the key list the category to which the evidence mentioned in the item belongs.

   A. Comparative Anatomy
   B. Comparative Physiology
   C. Classification
   D. Embryology
   E. Palaeontology

2.0 COMPREHENSION

2.1 TRANSLATION

10. Which of the following represents the best definition of the term 'protoplasm' ?
    - A. A complex colloidal system made up of water, proteins, and fats
    - B. Anything capable of growth by a regular progressive series of changes into a more complex unit
    - C. A complex mixture of proteins, fats, and carbohydrates, capable of responding to in its environment
    - D. A complex colloidal system of proteins, fats, carbohydrates, inorganic salts, and enzymes which manifests life

2.2 INTERPRETATION

11. Problem : You have learned that if plants are to grow they need water. You also know that plants lose water by transpiration. Imagine that a plant has some sort of mechanism by means of which all transpiration could be prevented. What else would happen ?
    - A. Food could not be digested.
    - B. The plant could not grow.
    - C. Water could not rise through the plant's stem.
    - D. The plant would grow even better than before.
    - E. Food could not be diffused.

2.3 EXTRAPOLATION

12. Suppose a river with a number of well-developed tributaries shows considerable lateral erosion. Which of the following characteristics would such a river also be expected to have ?
    - A. Rapids and waterfalls
    - B. A steep slope or gradient
    - C. Many narrow well-rounded divides
    - D. V-shaped walls
    - E. None of the above

3.0 APPLICATION

13. A tree is girdled (ringed) by cutting away a band of bark to the xylem around the trunk. Which of the following is most logical to assume concerning a tree that has been girdled ?
    - A. It dies immediately because the leaves no longer receive food and water from the roots.
    - B. It dies but not immediately because the leaves do not receive food and water from the roots.
    - C. It does not die as the removal of the bark does not materially affect the primary functions of the tree.
    - D. It dies because food can no longer be transported in the medullary rays.
    - E. It dies but not immediately because the roots starve when the stored food reserves are exhausted.

4.0 ANALYSIS

EXPERIMENT

Endoderm cells in 10 three-day-old chick embryos were marked with a vital stain (i. e., one which does not kill the cells). One embryo was killed and preserved immediately and every six hours thereafter for 30 hours a different embryo was sectioned and made into slides which were examined microscopically. The location of the stained cells was recorded. No stained cells appeared within the gonads. It was concluded that endoderm cells do not become germinal cells.

4.1 ANALYSIS OF ELEMENTS

14. What must be assumed if the results of this experiment are to be considered valid ?

    A. Endoderm cells usually form the gonads.
    B. Ectoderm cells become gametes.
    C. Gonads are comprised of cells from various parts of the embryo.
    D. The presence of stained cells indicates that they actively move.
    E. The vital stain does not affect the cell's functions.

4.2 ANALYSIS OF RELATIONSHIPS

15. How is the conclusion related to the experimental results ? It is probably

    A. valid but is not supported by the results.
    B. valid and is supported by the results.
    C. not valid but is supported by the results.
    D. not valid and is not supported by the results.
    E. not valid but is unrelated to the results.

4.3 ANALYSIS OF ORGANISATION PRINCIPLES

16. Which theory was the experiment most likely designed to investigate ?

    A. Darwin's theory of pangenesis
    B. Embryonic induction theory
    C. Theory of epigenesis
    D. Theory of inheritance of acquired characteristics
    E. Weismann's germ plasm theory

5.0 SYNTHESIS

5.1 PRODUCTION OF A UNIQUE COMMUNICATION

17. The idea of evolution by natural selection is widely credited to Charles Darwin although it had been discussed by several forerunners including Charles' grandfather. The 'cell theory' is commonly attributed to Schleiden and Schwann, although it had previously been described by Wolff and others. The use of binominal nomenclature in taxonomy of living organisms is not original with Linnaeus, although he is often given the credit for it.

    What common feature in this cases accounts for the attribution of fame to Charles Darwin, Schleiden and Schwann, and Linnaeus for developments in which they had been preceded ?

5.2 PRODUCTION OF A PLAN OR PROPOSED SET OF OPERATIONS

18. Which of the following is the best experimental procedure to determine the effectiveness of a vaccine in preventing influenza in parakeets ?
    - A. Expose 100 parakeets to the disease and inoculate 50 with the vaccine.
    - B. Inoculate 100 parakeets with the vaccine and expose all 100 to the disease.
    - C. Inoculate 50 with the vaccine and expose all 100 to the disease.
    - D. Inoculate 50 with the vaccine and expose those to the disease.
    - E. Inoculate 50 with the vaccine and 50 with sterile saline and then expose all 100 to the disease.

5.3 DERIVATION OF A SET OF ABSTRACT RELATIONS

19. Propose an hypothesis which will satisfactorily explain the following set of data :
    - A. A concerted attack on problems of plant and animal morphology characterised the eighteenth century.
    - B. A concerted attack on problems of plant and animal chemistry did not get under way until the nineteenth century.
    - C. A concerted attack on problems of plant and animal ecology did not get under way until the twentieth century.

6.0 EVALUATION

6.1 JUDGMENT IN TERMS OF INTERNAL CRITERIA

20. You are asked to classify cell organelles on the basis of their principal functions. One category you erect is for organelles whose chief function concerns cell division. Which of the following is the most likely representative of this category ?
    - A. Lysosome
    - B. Mitochondrion
    - C. Centriole
    - D. Ribosome
    - E. Golgi body

6.2 JUDGEMENT IN TERMS OF EXTERNAL CRITERIA

21. Mitochondria are called power houses of the cell because they make energy available to the cell's metabolism. Which of the following observations is most cogent in supporting this concept of mitochondrial function ?
    - A. ATP occurs at the mitochondria.
    - B. Mitochondria have a double membrane construction.
    - C. The enzymes of the Kreb's cycle and the cytochromes are found in mitochondria.
    - D. Mitochondria abound in muscle tissue.
    - E. Mitochondria are found in almost all kinds of plant and animal cells.

APPENDIX—B

Test Booklet

TAXONOMIC BIOLOGY ACHIEVEMENT TEST

based on

Bloom's Taxonomy of Educational Objectives

Time : 60 mts.

Marks : 60

DO NOT WRITE ANYTHING ON THIS BOOKLET

GENERAL INSTRUCTIONS

1. Answers are to be indicated on the separate answer sheet (Yellow) provided to you and NOT on the test booklet.
2. Write your Roll No., Class, Section, Name of the school, etc., on the space provided at the top of the answer sheet.
3. Do not turn over this page unless you are asked.

Nothing is to be written on this test booklet

Answers are to be indicated on the yellow answer sheet provided separately

Note : Read the instructions carefully before attempting the questions. This would save time and improve your score.

SPECIFIC INSTRUCTIONS

1. Do not read the whole test at a time. Start attempting from the very first question.
2. Go as fast as you can. Do not waste time on questions which you cannot answer immediately. Leave them and pass on to the next ones. You can try these questions once again towards the end if time permits.
3. Marks will be deducted for wrong answers. It is, therefore, advised not to make blind guess to answer a question. Attempt only those questions about the answer of which you are sure.
4. On each page of the test booklet six questions based on the same biological concept/principle, are given. Concentrate on those very six questions without distracting your attention on the questions given on other pages. Attempt each set of questions given on a page, one after the other.
5. In each of the questions, four answers A, B, C & D are provided. Out of these only one is correct. Select the right answer (A or B or C or D) and cross it out (×) in the answer sheet ONLY as shown in the following two examples E.1 and E.2.

EXAMPLES

E.1 Which of the following animals is a mollusc ?

A. Earthworm

B. Tape worm

C. Ship worm

D. Round worm

E.2 A seed can germinate in the absence of adequate

A. light.

B. moisture.

C. air.

D. warmth.

In question No. E.1 correct answer is C. Therefore in the answer sheet C is crossed like this '×' (See answer sheet for question E.1). Similarly in question E.2 correct answer is A which is cross marked as'×'in the answer sheet (check it).

Now try the following questions E.3 and E.4 for practice

E.3 Which of the following animals has a backbone ?

A. Hydra

B. Cockroach

C. Fish

D. Tape worm

E.4 Which of the following functions is served by the roots of a plant ?

A. Fixation of plant

B. Absorption of water

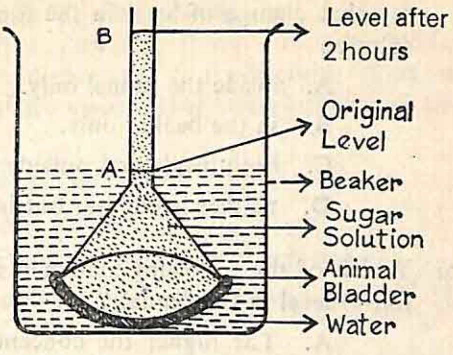
C. Storage of food

D. All the above.

Indicate by cross mark '×' the correct answer in the answer sheet against question Nos. E.3 and E.4

NOW PUT DOWN YOUR PEN/PENCIL AND WAIT FOR FURTHER INSTRUCTIONS.

Examine the diagram of the experimental setup and answer the questions that follow :



1 In this experiment animal bladder acts as a

A. cell.
B. cell wall.
C. cell membrane.
D. cell sap.

2 Animal bladder is used in this experiment because it allows to pass through it the molecules of

A. sugar more readily than water.
B. water more readily than sugar.
C. both sugar and water at the same rate.
D. neither sugar nor water.

3 What would be the effect on the level of solution in the funnel if sugar is also put in the beaker ?

A. It will go up.
B. It will come down.
C. It will remain unchanged.
D. It can be any of the above.

4 In this experiment a student guessed that with the addition of some sugar in the beaker, level in the funnel would come down. This guess could be correct if we assume that compared to funnel solution, the solution in the beaker has

A. more concentration.
B. less concentration
C. more volume.
D. less volume.

5 In this experiment the level in funnel rose from A to B after two hours. In the beaker some sugar was put and the level after some time came down in funnel. When more sugar was added the level inside the funnel became the same as outside. On further addition of sugar the level inside the funnel became lower than the level outside in the beaker. On the basis of these observations we can

say that change of level in the funnel depends on the concentration of sugar solution

A. inside the funnel only.
B. in the beaker only.
C. both inside and outside the funnel.
D. neither inside nor outside the funnel.

6 Which of the following statements BEST explains the mechanism of rise and fall of level in the funnel ?

A. The higher the concentration of sugar solution in the funnel, the more will be the rise in the level due to increased rate of transference of water particles from the beaker to the funnel.
B. The higher the concentration of sugar solution in the beaker the higher will be the rise in the funnel due to increased rate of transference of water particles from the beaker to the funnel.
C. The higher the concentration of sugar solution in the funnel the less will be the rise in level due to increased rate of transference of water particles from funnel to the beaker.
D. The higher the concentration of sugar solution in the beaker the less will be the rise in the level inside the funnel due to increased rate of transference of water particles from the beaker to the funnel.

7 Plasmolysis is a process in which the cells when suspended in a solution of higher concentration than that of the cells, the cytoplasm

A. becomes turgid.
B. gets shrunk.
C. dies.
D. retains its shape.

8 If sliced potatoes are put in plain water for some time they are likely to

A. swell and become turgid.
B. shrink and become limp.
C. shrink and become turgid.
D. retain the shape.

9 In which of the following examples the principle of plasmolysis is NOT applicable ?

A. Use of sugar in preserving jam
B. Use of salt for keeping pickles free from moulds
C. Limping of potato slice when put in salt water
D. Swelling of raisins when put in plain water

10 When sliced potatoes were put in plain water they became crisp (turgid) but when placed in salt water they became limp (shrunk). It was concluded that it was due to endomosis in the first case and exomosis in the second. This inference can be considered correct only if we assume that concentration of the cell sap in potato is

A. more than that of plain water and salt water.
B. less than that of plain water and salt water.
C. more than that of plain water but less than that of salt water.
D. more than that of salt water and less than that of plain water.

11 When sliced potatoes were placed in plain water they became turgid. When placed in salt water they remained as they were. From this observation we can hypothesise that concentration of the cell sap in potato is

A. less than that of plain water and salt water.
B. less than that of salt water and more than that of plain water.
C. more than that of plain water and same as that of salt water.
D. more than that of salt water and plain water.

12 If concentration of solution of cell sap in potato is more than that of water and salt solution which of the following predictions is most likely to be true in this context ?

Potato slices would become

A. crisp in water but limp in salt solution.
B. crisp in salt solution and limp in plain water.
C. crisp in both plain and salt water.
D. limp in both plain and salt water.

13 Which of the following enzymes is produced from the salivery glands ?

A. Trypsin
B. Ptyalin
C. Pepsin
D. Erepsin

14 Which of the following enzymes bears the same relationship to Intestinal glands as pepsin to gastric glands ?

A. Lipase
B. Pepsin
C. Amylase
D. Ptyalin

15 Which of the following foods would NOT be digested if gastric glands do not function ?

A. Butter
B. Sugar
C. Egg
D. Rice

16 Two enzymes act on the same food constituents in two different organs of the digestive system leading to the same end-products. Which of the following pairs of enzymes could it be ?

A. Trypsin and Amylase
B. Ptyalin and Trypsin
C. Pepsin and Trypsin
D. Lipase and Amylase

17 Amylase converts starch into sugar in the mouth. But it stops acting when food reaches the stomach. Another amylase produced from pancreas starts acting to convert starch into maltose. Which of the following hypotheses explains this phenomenon ?

A. Amylase is not specific in its action.
B. Amylase acts only in acidic medium.
C. Amylase acts only in alkaline medium.
D. Amylase acts both in acidic and alkaline media.

18 Some enzymes are functional in acidic medium while others function in alkaline medium. This is why pepsin is functional in stomach because it has alkaline juices. In this statement about pepsin

A. inference is correct but reasoning is incorrect.
B. inference is incorrect but reasoning is correct.
C. inference as well as reasoning is correct.
D. neither inference nor reasoning is correct.

19 Which of the following cell organelles acts as a site for photosynthesis ?

A. Mitochondrion
B. Chloroplast
C. Ribosome
D. Nucleus

20 Functional relationship between nucleus and cell division is the same as between chloroplast and

- A. respiration.
- B. secretion.
- C. photosynthesis.
- D. protein synthesis.

21 If a potted plant is shifted from the open place to a dark room which of the following cell organelles would probably stop functioning ?

- A. Ribosome
- B. Chloroplast
- C. Cell membrane
- D. Mitochondrion.

22 On examining a cell under the electron microscope a number of vacuoles, mitochondria, cell membrane and nucleus were observed by a student who identified it as a plant cell. Before arriving at this conclusion he should have looked for another organelle concerned with ability to

- A. photosynthesise
- B. respire
- C. secrete
- D. reproduce

23 Mitochondria and chloroplasts are commonly found organelles in a typical cell. Sometimes both are present in the same cell but sometimes chloroplasts may be absent. The logical conclusion from this observation would be that every cell can

- A. respire and photosynthesise.
- B. respire but not photosynthesise.
- C. photosynthesise but not respire.
- D. neither photosynthesise nor respire.

24 Chloroplasts are sometimes called the food manufacturing units of a plant cell because they UTILISE the sun's energy for metabolic activities of the cell. Which of the following functions supports this view of chloroplast ?

- A. Formation of $NADPH_2$
- B. Synthesis of ATP
- C. Decomposition of water
- D. All the above functions

25 In the experiment to show that chlorophyll is necessary for photosynthesis, the LAST step is to

A. take a variegated leaf exposed to sunlight.
B. kill the leaf in boiling water and then in spirit.
C. put it under the iodine solution.
D. note the areas which are green in colour.

26 In this experiment the purpose of treating leaf in boiling water and then in alcohol is to

A. remove starch from the leaf.
B. see which portions have starch.
C. dissolve chlorophyll from the leaf.
D. note whether leaf turns blue black.

27 In this experiment if a totally green leaf is used in place of a variegated leaf it would NOT be possible to

A. apply the starch test.
B. remove the starch from the leaf.
C. dissolve the chlorophyll fully.
D. draw inference from the starch test.

28 A leaf was immersed in boiling water and then kept in hot spirit. After washing when tested it did not show the presence of starch. It was concluded that certain leaves do not have chlorophyll. This conclusion may be regarded as correct if we assume that the leaf used was

A. variegated and not totally green.
B. totally green and not variegated.
C. not previously exposed to sunlight.
D. previously exposed to sunlight.

29 To test the hypothesis that chlorophyll is necessary for photosynthesis, a variegated leaf was immersed in boiling water and then kept in hot spirit. After washing when iodine test was applied it did not show the presence of starch. The most probable inference that can be drawn from this observation is that the leaf used was

A. previously exposed to sunlight.
B. previously kept in dark for some days.
C. variegated and not totally green.
D. decolourised by treating with spirit.

30 A variegated leaf was immersed in boiling water and then kept in hot spirit. After washing when tested, it showed absence of starch. Which of the following explanations supports the results ?

Leaf used was

- A. not previously exposed to sunlight and starch was not present in it.
- B. previously exposed to bright sunlight that resulted in excessive starch.
- C. deprived of starch when treated with boiling water and hot spirit.
- D. without chlorophyll and thus no starch was formed.

31 Moll's half leaf experiment demonstrates that for photosynthesis

- A. water is necessary.
- B. chlorophyll is necessary.
- C. carbon dioxide is necessary.
- D. oxygen gas is necessary.

32 In Moll's experiment which of the following conditions for photosynthesis is NOT common to the two portions of the leaf, one inside the bottle and the other outside it ?

- A. Light
- B. Chlorophyll
- C. Carbon dioxide
- D. Water

33 If instead of half the leaf we introduce the whole leaf in the bottle in Moll's experiment then the MOST appropriate inference would have been that

- A. carbon dioxide is essential for photosynthesis.
- B. light is necessary for starch formation.
- C. carbon dioxide prevents starch formation.
- D. starch is not formed in the absence of carbon dioxide.

34 In Moll's experiment the leaf part OUTSIDE the bottle did NOT show presence of starch. This observation can be correct only when we assume that the apparatus was kept

- A. in the sunlight for several hours.
- B. in dark for several days.
- C. with KOH in the bottle.
- D. without KOH in the bottle.

35 In Moll's experiment in leaf portion inside the bottle did not show presence of starch. When KOH was not kept inside the bottle and the glass bottle was covered with black paper the iodine test again showed absence of starch in the leaf portion inside the bottle. Which of the following possible conclusions could be drawn from THESE observations?

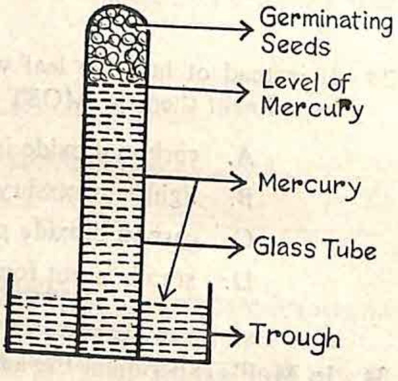
A. Carbon dioxide and not light is necessary for starch formation.
B. Light and not carbon dioxide is essential for photosynthesis.
C. Both light and carbon dioxide are necessary for starch formation.
D. Neither carbon dioxide nor light is necessary for starch formation.

36 In the Moll's experiment the glass bottle was covered with black paper and tested for starch after a few hours. No starch was found in that part of leaf which was inside the bottle. Which of the following statements is NOT relevant to the observed phenomenon ?

A. Both CO_2 and light which are essential for starch formation, are prevented by KOH and black paper respectively.
B. Light is essential for starch formation and therefore, leaf could not photosynthesise when it was covered with black paper.
C. Due to the presence of KOH solution supply of CO_2 was cut off thus preventing photosynthesis.
D. Both light and CO_2 supply was cut off due to black paper thus preventing photosynthesis.

37 Anaerobic respiration is an intracellular process of

A. oxidation in the presence of air.
B. mere gaseous exchange.
C. conversion of solar energy into chemical energy.
D. oxidation in the absence of air.



38 If more germinating seeds are introduced in the tube the level of mercury in the tube is likely to

A. rise immediately.
B. rise after some time.
C. fall after some time.
D. remain at the same level.

39 In this experiment if boiled seeds are used in place of germinating seeds mercury level remains the same. This is because boiled seeds

A. do not respire.

B. respire only in the absence of air.

C. do not photosynthesise.

D. respire only in the presence of air.

40 In this experiment when mercury tube is completely filled and the germinating seeds are introduced they respire to give CO_2 and ethyl alcohol as end-products. But when mercury tube is only half filled before introducing the germinating seeds then CO_2 and water are the end-products. This is because there is

A. glycolysis in anaerobic but not in aerobic respiration.

B. glycolysis in aerobic but not in anaerobic respiration.

C. Kreb's cycle in anaerobic but not in aerobic respiration.

D. Kreb's cycle in aerobic but not in anaerobic respiration.

41 When germinating seeds are used in this experiment glucose breaks down into ethyl alcohol and carbon dioxide. On this basis it can be concluded that this break down is

A. aerobic involving Kreb's cycle.

B. anaerobic involving Kreb's cycle.

C. aerobic involving glycolysis.

D. anaerobic involving glycolysis.

42 Anaerobic respiration is an intracellular process of oxidation. To understand the difference in the mechanism of aerobic and anaerobic respiration, this statement is

A. adequate to explain the mechanism of respiration.

B. inadequate because it does not indicate whether end-products are the same or not.

C. inadequate because it does not explain whether energy is released or not.

D. inadequate because it does not indicate whether glycolysis occurs in both.

43 In which of the following organisms there is NO need of an internal transport of materials ?

A. Paramoecium

B. Earthworm

C. Cockroach

D. Man

44 A closed circulatory system is one in which blood

A. enters the heart directly from body spaces.

B. moves through blood plasma.

C. flows through intercellular spaces.

D. travels through arteries and veins.

45 A multicellular organism which is thin, flattened like a leaf and profusely branched is best adapted for transportation of substances through

A. haemoglobin of blood.

B. direct diffusion.

C. blood vessels.

D. intercellular spaces.

46 In an organism if the circulating fluid for transporting food substances it can be man only, provided we are sure that system of transportation is through

A. direct diffusion from cell to cell.

B. intercellular spaces.

C. closed vessels.

D. plasma fluid.

47 In Amoeba internal transport occurs through diffusion ; in insects it is through intercellular spaces and in man it is through blood vessels. This variation in the system of transport can be attributed mainly to

A. complexity of structure.

B. nature of food substances.

C. type of circulatory fluid.

D. mode of nutrition.

48 Which of the following types of organisms is more likely to become adapted to the type of circulatory system of transportation as in man ?

A. A kind of arthropod

B. A kind of coelenterate

C. A kind of annelid

D. A kind of protozoan

49 Which of the following tissues conducts food from the leaves to the stem ?

A. Phloem

B. Xylem

C. Pith

D. Cortex

50 Which part of the conducting tissue will get stained if a cut portion of the stem of a balsam plant is kept in coloured water for an hour ?

A. Phloem only
B. Xylem only
C. Both xylem and phloem
D. Neither xylem nor phloem

51 When a dicot stem is given a slightly deep cut in the form of a ring it results in swelling just above the cut due to restriction of

A. upward movement of water and mineral salts.
B. downward movement of water and mineral salts.
C. upward movement of food materials.
D. downward movement of food materials.

52 When the stem of a dicot plant is girdled a swelling appears just above the cut. This inference can be considered correct only if we assume that girdling is done to the extent that

A. only phloem is cut.
B. only xylem is cut.
C. both phloem and xylem are cut.
D. neither phloem nor xylem is cut.

53 Read the following four statements and answer the question that follows :

I. Swelling appears just above the cut in the dicot stem when girdled.
II. Leaves wilt if the cut portion of balsam plant is put in wax.
III. Xylem tissue is stained when a cut stem of balsam plant is placed in coloured water.
VI. Roots starve when a dicot stem is girdled.

Which of the following hypotheses explains the above phenomena ?

A. Both xylem and phloem are concerned with downward movement of water.
B. Phloem is concerned with upward movement of water and xylem with downward movement of food materials.
C. Xylem is concerned with the upward movement of water and phloem with downward movement of food materials.
D. Both phloem and xylem are concerned with the upward movement of water.

54 A swelling appears just above the cut in a dicot stem when ringed. Which of the following statements justifies this phenomenon ?

- A. Xylem is cut away by ringing and thus translocation of food from leaves to roots is checked resulting in swelling.
- B. When xylem is cut away by ringing, translocation of food to leaves from other parts is checked and causes swelling.
- C. When phloem is cut away by ringing, translocation of food from the leaves to other parts is checked and causes swelling.
- D. Phloem is cut away by ringing and thus obstructs the upward movement of food resulting in swelling.

55 In which of the following plants stomata are generally found on the upper surface of leaves ?

- A. Hydrilla
- B. Lotus
- C. Vallisneria
- D. Pistia

56 In aquatic plants if stomata are on the lower surface of leaves it would facilitate

- A. transpiration.
- B. respiration.
- C. photosynthesis.
- D. none of the above.

57 If upper surface of leaves of aquatic plants is smeared with vaseline it would NOT affect the

- A. transpiration process.
- B. photosynthetic activity.
- C. absorption of water.
- D. respiration process.

58 Mesophytic plants get rid of excess water through lower surface of their leaves. But this is not true of aquatic plants. This can be explained by the fact that in aquatic plants generally the

- A. leaves have no stomata on either side and thus no transpiration takes place.
- B. leaves have stomata on both side of leaves through which transpiration occurs.
- C. leaves have stomata on both sides to get rid of water by transpiration.
- D. leaves have stomata on lower side but do not open thus preventing transpiration.

59 It is said that in aquatic plants transpiration takes place through upper surface of the leaf. Which of the following experimental procedures would be most suited to test this hypothesis ?

Smear a few leaves with vaseline on their

A. upper surface and observe if they rot.

B. lower surface and observe if they rot.

C. both surface and observe if they rot.

D. neither surface and observe if they rot.

60 Which of the following statements is consistent with the known facts about transpiration in aquatic plants ?

A. If lower surface of leaves is waxed, transpiration stops and leaves rot.

B. If upper surface of leaves is waxed, transpiration stops and the leaves rot.

C. If upper surface of leaves is waxed, transpiration is not affected and leaves do not rot.

D. If lower surface of leaves is waxed, transpiration is not affected but leaves rot.

APPENDIX—C

ANSWER SHEET

(Biology Achievement Test)

Age : ....years and ......months

Date : ....

Time : 60 minutes

Roll No. : .. ..Boy/Girl

Class : ....Section.......

School : ....

Total marks	60
No. Correct	
No. Wrong	
No. Omitted	
Correct score	

	Examples			For practice	
	E.1 A B [✓ C] D	E.2 [✓ A] B C D		E.3 A B C D	E.4 A B C D

Set I	1 A B C D	2 A B C D	3 A B C D	4 A B C D	5 A B C D	6 A B C D
Set II	7 A B C D	8 A B C D	9 A B C D	10 A B C D	11 A B C D	12 A B C D
Set III	13 A B C D	14 A B C D	15 A B C D	16 A B C D	17 A B C D	18 A B C D
Set IV	19 A B C D	20 A B C D	21 A B C D	22 A B C D	23 A B C D	24 A B C D
Set V	25 A B C D	26 A B C D	27 A B C D	28 A B C D	29 A B C D	30 A B C D
Set VI	31 A B C D	32 A B C D	33 A B C D	34 A B C D	35 A B C D	36 A B C D
Set VII	37 A B C D	38 A B C D	39 A B C D	40 A B C D	41 A B C D	42 A B C D
Set VIII	43 A B C D	44 A B C D	45 A B C D	46 A B C D	47 A B C D	48 A B C D
Set IX	49 A B C D	50 A B C D	51 A B C D	52 A B C D	53 A B C D	54 A B C D
Set X	55 A B C D	56 A B C D	57 A B C D	58 A B C D	59 A B C D	60 A B C D

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